An Assessment of the United States Measurement System:

Addressing Measurement Barriers to Accelerate Innovation

Appendix H

Analysis of Case-Study Measurement Needs: Summary Report

NIST Special Publication 1048

NIST
National Institute of Standards and Technology
Technology Administration, U.S. Department of Commerce

U.S. Measurement System

Measurement Need (MN) Data Book

Prepared by
Energetics Incorporated
for the
National Institute of Standards and Technology

April 2006

Introduction
SECTOR CHAPTERS

1. Building and Construction
2. Chemicals, Industrial Biotechnology, and Continuous Manufacturing
3. Defense and Homeland Security (including First Responder)
4. Electronics Non-Semiconductor and Information Technology (IT) Hardware
5. Electronics Semiconductor
6. Energy and Power and Environment
7. Healthcare (including Bioimaging)
8. Manufacturing (Discrete) and Automotive
9. Materials
10. Nanotechnology
11. Software for Information Technology (IT)
12. Assessment of all Economic Sectors/Areas Assessed

Introduction

The U.S. Measurement System (USMS) Measurement Need (MN) Data Book contains a series of correlation tables and distribution charts based on over 300 one-page measurement need summaries developed by NIST for various sectors of the economy as well as technology areas. The supporting data for each table and chart was derived from individual MNs through a "tagging" process designed to gather a consistent set of information from each MN. The tags were developed from the perspective of providing key information about measurement providers, solutions, and barriers, as well as other parameters. Each table and chart provides results for selected tags or sets of tags. The methodology and the set of tags used is discussed in more detail in "An Approach for Inferring the State of the USMS from the MN Analysis, Roadmap Analysis, and USMS Characterization."

It should be noted that for each MN, there are multiple choices for some sets of tags. For example, up to three tags are possible for measurement solutions, measurement barriers, measurement providers, and selected other tags. Consequently, the total number of "hits" in a single chart or table may exceed the number of MNs in that sector. On tables and charts where this occurs, MN Element is used rather than MN on the vertical axis to reflect that multiple tags may be selected for some categories.

The information contained in these tables and charts is integral to the inferential methodology that is being used by NIST to assess the state of the USMS. Different inferences, for example, might be drawn by looking at simple histograms or distributions of tags, or by combining tags in various ways. Both correlation tables and distribution charts may be used to identify and support findings about the USMS, particularly within the sector of interest. The utility of both approaches is outlined below.

Correlation Tables

Correlation tables compare one set of tags with another to help discern synergies, identify areas of greatest emphasis (and those of no interest), and possibly point to key problem areas within a sector or technology. Each table has two sets of parameters being compared or correlated – and these are noted in the title of the table.

Each cell in the table indicates the juncture of two parameters, and the number (if any) in the cell indicates the number times that juncture occurred in the set of MNs analyzed. Cells shaded in blue indicate a higher number of junctures; green shading indicates a lower number. For example, the correlation table for Healthcare comparing Measurement Solution Barriers with Measurement Solutions might have a number of 20 in the blue-shaded cell corresponding to Accuracy (barrier) and Measurement Instrument (solution). This means that 20 MNs were tagged with Accuracy as a barrier and with Measurement Instrument as a solution. This tells us that within the Healthcare sector, accuracy is a primary measurement challenge, and new instrumentation is one of the key solutions.

Correlations may also point out anomalies. For example, if a large number of MNs were tagged with "lack of fundamental knowledge" as a measurement barrier, you would expect that providers of fundamental measurement science or research would emerge as key providers. If this were not the case, it might point to a key finding about how measurement needs are communicated within the USMS.

Distribution Charts

Distribution charts are simple histograms that summarize the number of times a particular tag was selected for the set of MNs in a sector. These provide a good sense of what the key issues are within a sector, and may be used as supporting evidence for an inferential finding. Distribution charts are titled with the primary category of the tags (measurement solution, measurement barrier, etc). All of the distribution charts use vertical bars to display the number of "MN elements" for each tag within the group (shown along the horizontal axis). For example, a histogram for measurement solutions will have 23 tags on the horizontal axis. All tags are represented on the charts, even if none were selected for that group of MNs (zero, or no bar visible).

U.S. Measurement System

Measurement Need (MN) Data Book

Chapter 1. Buildings and Construction

(Includes Residential / Commercial Building, and Civil Infrastructure)

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Reference List of MN Distribution Charts and MN Correlation Matrices

Exhibit 1.1: MN Distribution of Measurement Barriers in Buildings and Construction

Acceptibility	Accessibility	Accuracy	Data, Data Collection & Retrieval	Destructive	Expense	Lack of Fundamental Knowledge	Multiple Solutions	Not Standardized	Production Readiness	Reliability	Resolution	Small market demand	Speed	Systems-level	Workforce	Total
3	0	7	13	0	1	4	3	9	1	5	1	0	1	1	0	49

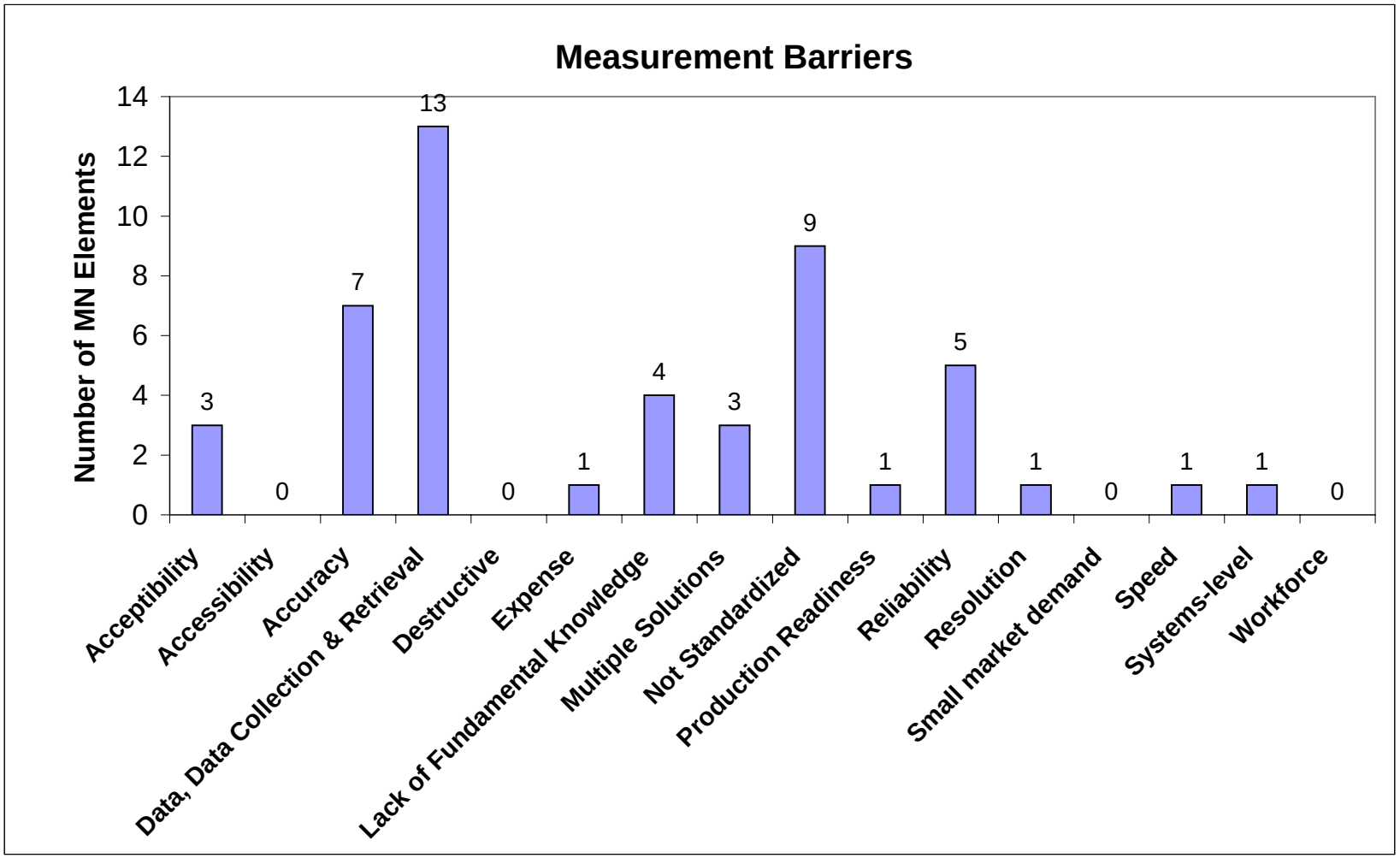

Exhibit 1.2: MN Distribution of Measurement Solution Providers in Buildings and Construction

Calibration Laboratories	Commercial Calibration Service Providers	Component Suppliers	Contractor R&D Labs-for-Hire	Engineering Management/Consulting Firms/A&E Firms	Government Laboratories and Agencies	Independent Testing/Certification Laboratories	Industrial R&D Laboratories	Industry Consortium/ Partnership	Instrument Suppliers	Material Suppliers	National Measurement Institute	Small Business/Inventors	Software Developers	Standards Development Organizations (SDO)	Testing Laboratories	Universities	Total
0	0	2	0	0	11	3	5	7	3	1	15	0	1	8	1	8	65

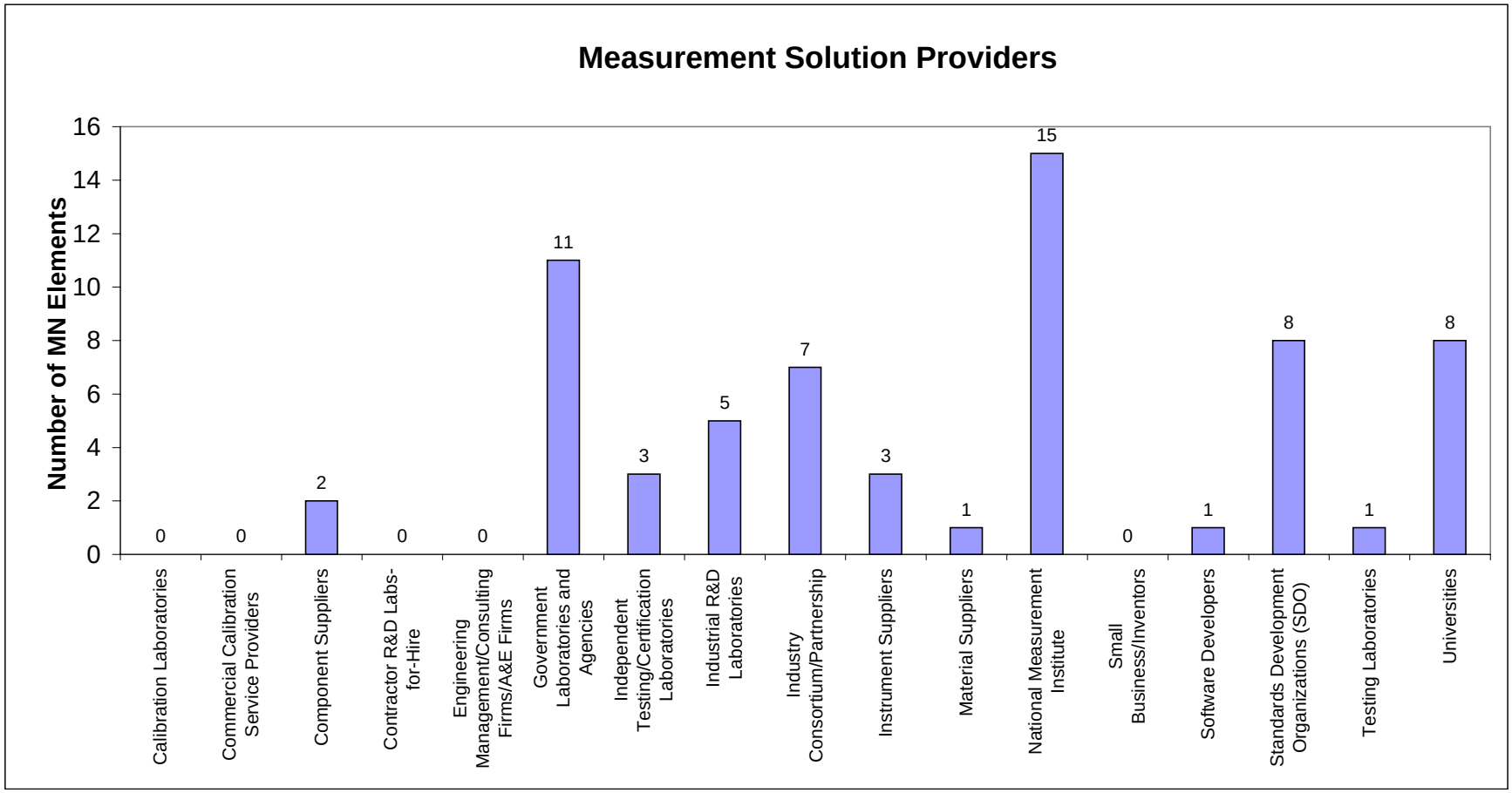

Exhibit 1.3: MN Distribution of Measurement Solutions in Buildings and Construction

Infrastructure								Products												Services				
Coordination/Facility	Data Collection/Retrieval	Development - Measurement Technology	Fund-amental Knowledge	Protocols	Research - Measure-ment Science	Standards	User Facility	Calibration	Computational Methods	Measure-ment Instrument	Measure-ment Method	Metrics/Benchmarks	Raw Data	Reference Data	Software	Stability Tests	Standard/certified reference material	Test methods for production-scale measurements	Test methods or test data for consumer products	Validated (hardened) properties data	Calibration	Expert consultation	Intl Recognition	Third Party Verification	Total
0	2	5	2	2	6	11	0	0	7	2	7	5	2	3	0	0	1	2	4	2	0	0	0	1	64

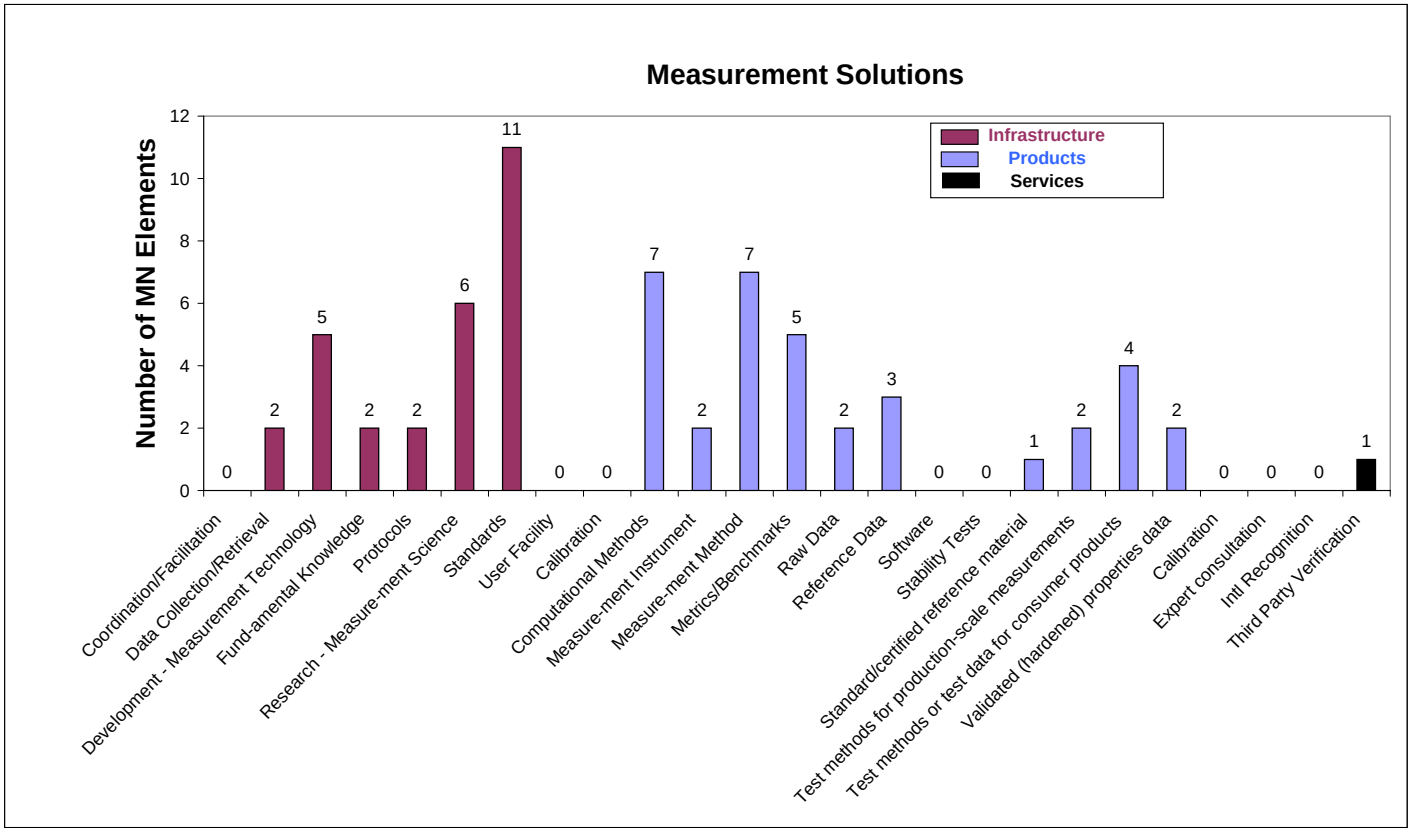

Exhibit 1.4: MN Distribution of Measurands in Buildings and Construction

Classical				Functional									Performance			Structural				
Biological	Chemical	Physical	Physiological	Acoustical	Electronic/ Electrical	Magnetic	Optical	Photonic	Radio frequency	Thermal- Thermochemical	Thermal- Thermodynamic	Thermal- Thermophysical	Computational Performance	Software Performance	System Performance	Kinetic	Mechanical	Molecular	Spatial	Total
0	1	3	2	0	3	0	0	1	0	0	1	4	1	0	3	0	2	0	2	23

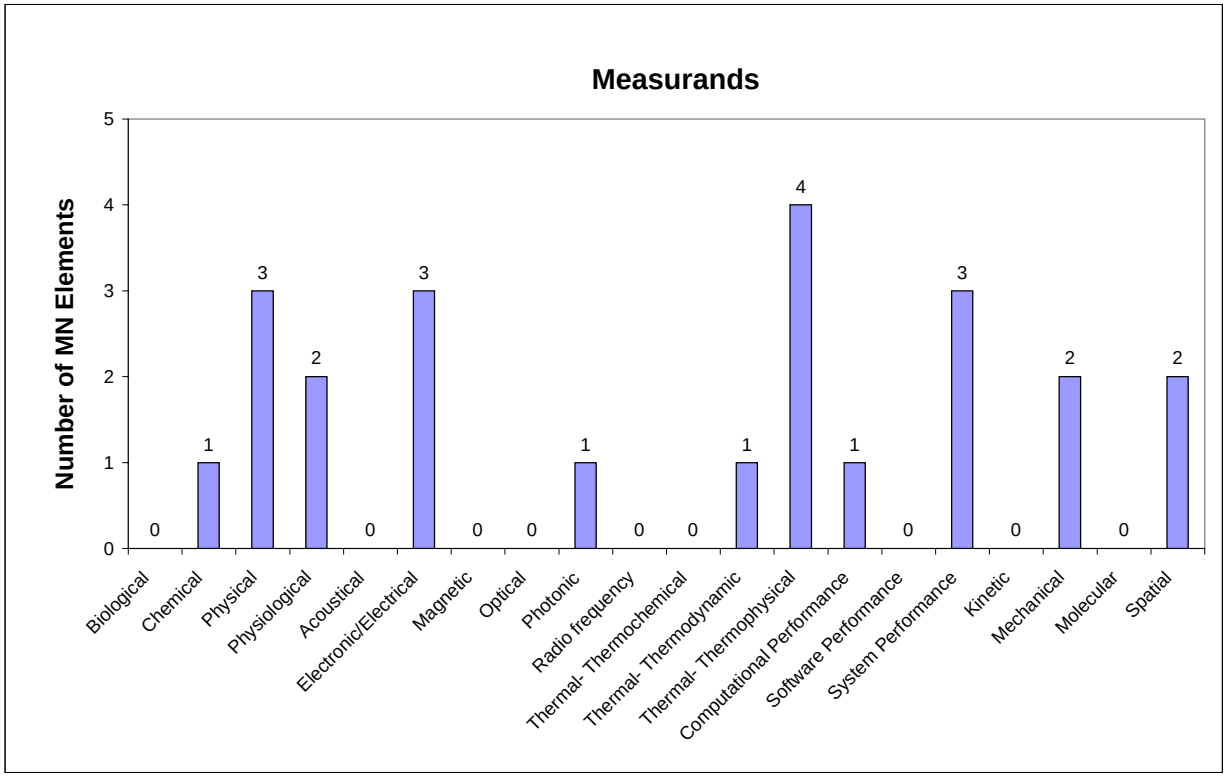

Exhibit 1.5: MN Distribution of Current Public/Private R&D Efforts in Buildings and Construction

Only Private Efforts Exist	Only Public Efforts Exist	Both Public and Private Efforts Exist	No Efforts Exist
1	2	4	16

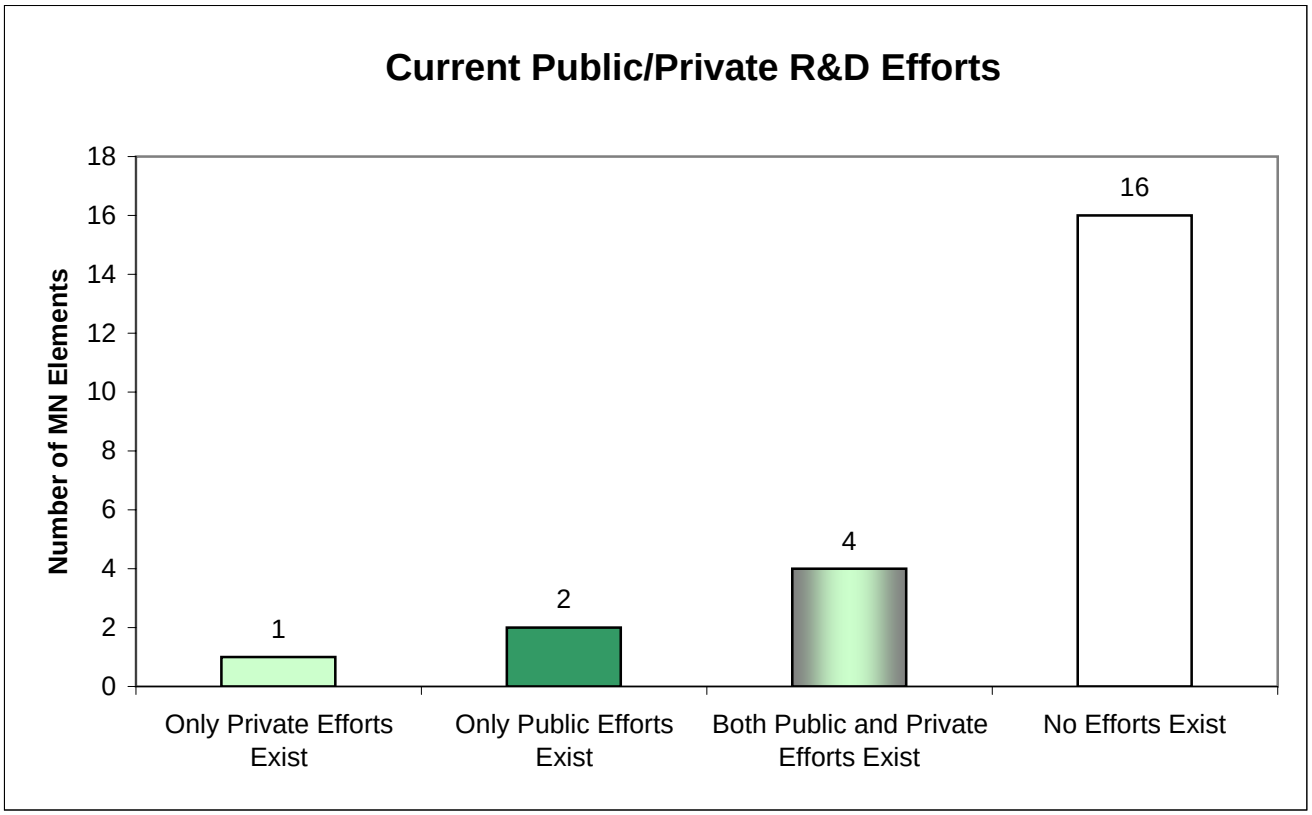

Exhibit 1.6: MN Distribution of TI as Measurement Technology in in Buildings and Construction

Technology Innovation is a Measurement Innovation	Technology Innovation is not a Measurement Innovation
7	16

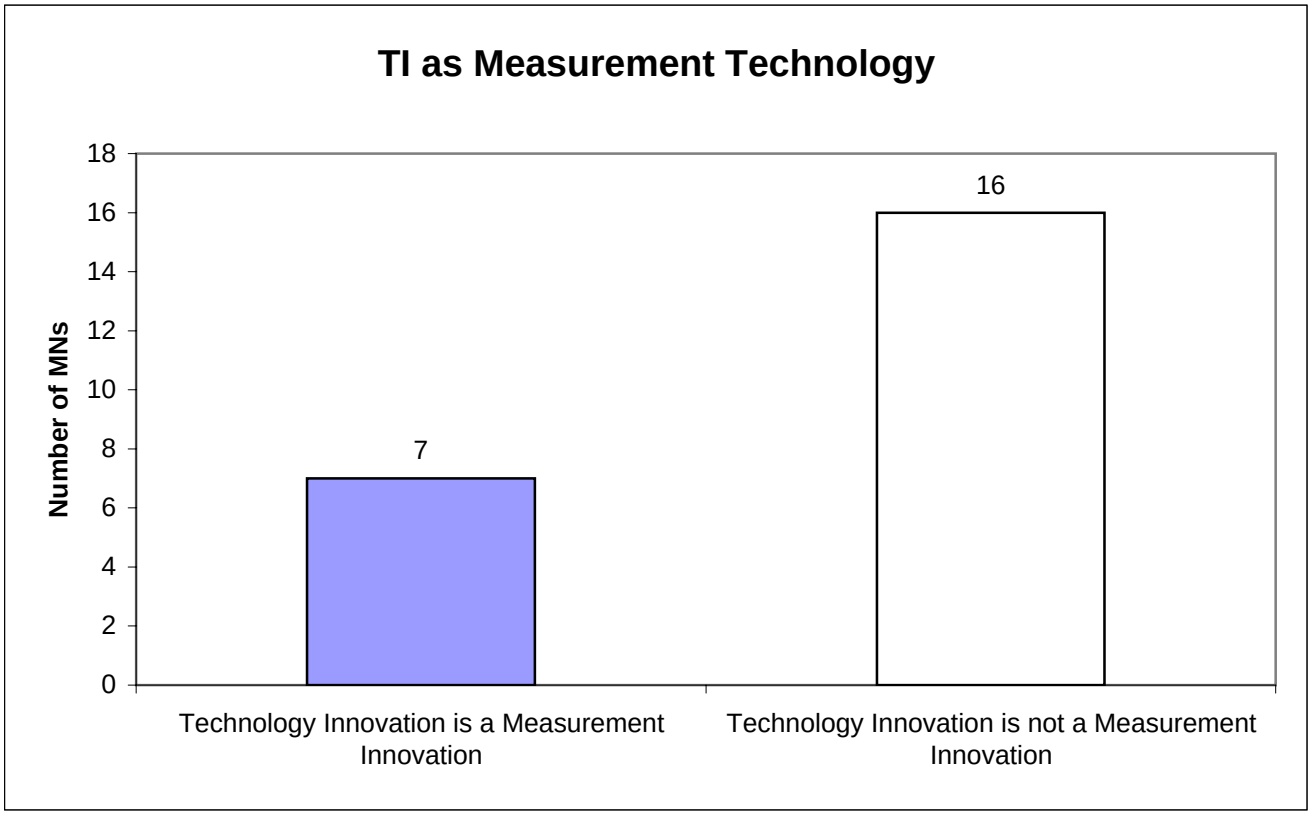

Exhibit 1.7: MN Distribution by Stage of Technological Innovation in Buildings and Construction

Applied Research	Production	Market	End-use	Total
13	1	8	1	23

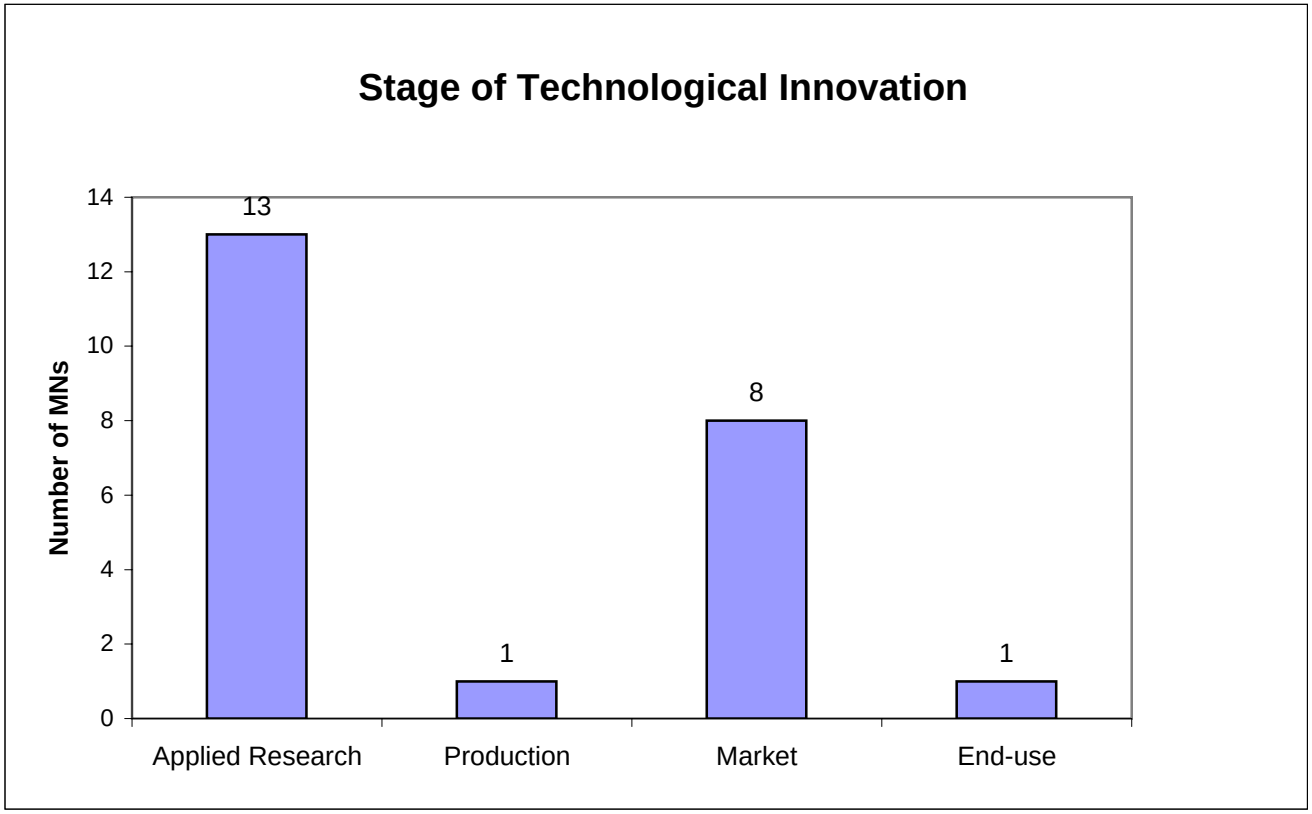

Exhibit 1.8: MN Distribution of Regulation as Driver/Barrier in Buildings and Construction

MN Driver	MN Barrier	No Impact
1	2	20

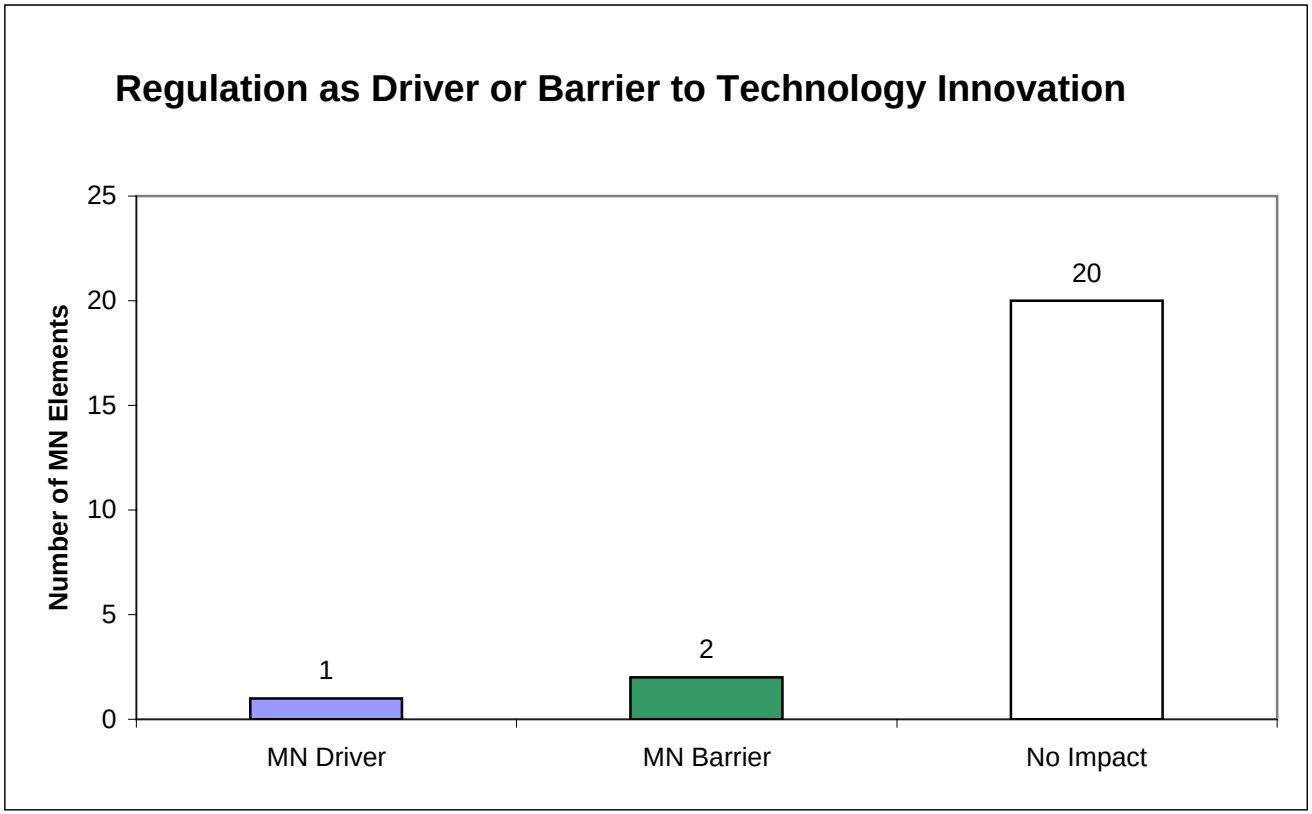

Exhibit 1.9: MN Correlation Matrix for Solution Providers and Measurement Barriers in Buildings and Construction

Solution Providers	Measurement Solution Barriers															
	Acceptability/Compatibility	Accessibility	Accuracy	Data, Data Collection and/or Retrieval	Destructive	Expense	Lack of fundamental knowledge	Multiple Solutions Exist	Not Standardized	Production Readiness	Reliability	Resolution	Small Market Demand	Speed	System-Level Problem	Workforce
Calibration laboratories																
Commercial calibration service providers																
Component suppliers	1		1	1				1	1							
Contractor R&D labs-for-hire																
Engineering management/consulting firms/A&E firms																
Government laboratories and agencies	1		3	7		1	1	1	4	1	2			1		
Independent testing/certification laboratories			2	2			1				2					
Industrial R&D laboratories			3	2					1	1	2					
Industry consortium/partnership	1		1	4			2	1	4		2				1	
Instrument suppliers	1		1	2					2			1				
Material suppliers				1			1									
National Measurement Institute	2		3	8		1	3	2	7		3	1		1	1	
Small business/inventors																
Software developers	1		1	1												
Standards development organizations (SDOs)			3	4				2	6		1	1				
Testing laboratories			1					1	1							
Universities	1		1	5			2	1	1	1	2					

Exhibit 1.10: MN Correlation Matrix for Measurement Barriers and Measurement Solutions in Buildings and Construction

	Measurement Solutions																									
	Infrastructure								Products															Services			
Measurement Solution Barriers	**Coordination/ facilitation**	**Data Collection/ Retrieval**	**Development for Measurement Technology**	**Fundamental Scientific Knowledge**	**Protocols**	**Research for Measurement Science**	**Standards**	**User Facility**	**Calibration Method**	**Computation Method**	**Measurement Instrument**	**Measurement Method**	**Metrics/ Benchmarks**	**Raw Properties Data**	**Reference Data**	**Software**	**Stability Tests**	**Standard/CRM**	**Test Methods - Production Scale**	**Test Methods - Consumer Products**	**Validated Data**	**Calibration Services**	**Expert Consultation**	**International Recognition**	**3rd Party Verification**
Acceptability/Compatibility			1	1		2	2			1		1	1													
Accessibility																										
Accuracy			2			3	2			3	1	4	2					1	1							
Data, Data Collection/and or Retrieval		2		1	2	2	5			6	2	3	3	1	2				2	3	2					
Destructive																										
Expense		1								1					1											
Lack of Fundamental Knowledge			1	2		3	3			1	1										1					
Multiple Solutions Exist			1				2				1	3		1												1
Not Standardized			2		2	1	8			1	1	3	1	1					1	4	1					1
Production Readiness			1											1	1											
Reliability		1	2			2	2			3		1	2							1						
Resolution							1						1							1						
Small Market Demand																										
Speed		1								1					1											
System-Level Problem			1			1																				
Workforce																										

Exhibit 1.11: MN Correlation Matrix for Measurement Providers and Measurement Solutions in Buildings and Construction

	Measurement Solutions																									
	Infrastructure								Products															Services			
Measurement Solution Providers	**Coordination/ facilitation**	**Data Collection/ Retrieval**	**Development for Measurement Technology**	**Fundamental Scientific Knowledge**	**Protocols**	**Research for Measurement Science**	**Standards**	**User Facility**	**Calibration Method**	**Computation Method**	**Measurement Instrument**	**Measurement Method**	**Metrics/ Benchmarks**	**Raw Properties Data**	**Reference Data**	**Software**	**Stability Tests**	**Standard/CRM**	**Test Methods - Production Scale**	**Test Methods - Consumer Products**	**Validated Data**	**Calibration Services**	**Expert Consultation**	**International Recognition**	**3rd Party Verification**
Calibration laboratories																										
Commercial calibration service providers																										
Component suppliers							1			1		2	1													1
Contractor R&D labs-for-hire																										
Engineering management/consulting firms/A&E firms																										
Government laboratories and agencies		2	2		1	3	4			2	1	3	1	2	3			1	1	2	1					
Independent testing/certification laboratories		1				2	1			2	1	1	1													
Industrial R&D laboratories			2			2	2			1		1	1	1	1				1	1	1					
Industry consortium/partnership			3	1	1	2	5			2		2	1						1	1	1					
Instrument suppliers					1		2			1		1	2						1	1						
Material suppliers				1			1														1					
National Measurement Institute		1	3	1	1	4	7			5	2	4	3	1	2			1		4	1					1
Small business/inventors																										
Software developers										1		1	1													
Standards development organizations (SDOs)			1		2	1	6			1		3	1					1	2	3						1
Testing laboratories			1				1					1														
Universities		1	2	2		1	2			3	1	2	3	2	2						1					

Exhibit 1.12: MN Correlation Matrix for Stage of Technological Innovation and Measurement Barriers in Buildings and Construction

Stage of Technological Innovation	Measurement Solution Barriers															
	Acceptability/Compatibility	Accessibility	Accuracy	Data, Data Collection and/or Retrieval	Destructive	Expense	Lack of fundamental knowledge	Multiple Solutions Exist	Not Standardized	Production Readiness	Reliability	Resolution	Small Market Demand	Speed	System-Level Problem	Workforce
Applied Research	1		6	5			2	2	4	1	3	1			1	
Production				1							1					
Market	2		1	6			2	1	5		1					
End-use				1		1								1		

Exhibit 1.13: MN Correlation Matrix for Stage of Technological Innovation and Measurement Solutions in Buildings and Construction

	Measurement Solutions																								
	Infrastructure								Products													Services			
Stage of Technological Innovation	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Applied Research			4	1	1	3	6			3	1	5	3	1	2			1		2	1				1
Production		1								1			1												
Market			1	1	1	3	5			2	1	2	1	1					2	2	1				
End-use		1								1					1										

Exhibit 1.14: MN Correlation Matrix for Solution Providers and Stage of Technological Innovation in Buildings and Construction

Measurement Solution Providers	Stage of Technological Innovation			
	Applied Research	Production	Market	End-use
Calibration laboratories				
Commercial calibration service providers				
Component suppliers	2			
Contractor R&D labs-for-hire				
Engineering management/consulting firms/A&E firms				
Government laboratories and agencies	5	1	4	1
Independent testing/certification laboratories	2	1		
Industrial R&D laboratories	3		2	
Industry consortium/partnership	3		4	
Instrument suppliers	2		1	
Material suppliers	1			
National Measurement Institute	8		6	1
Small business/inventors				
Software developers	1			
Standards development organizations (SDOs)	5		3	
Testing laboratories	1			
Universities	4	1	3	

Exhibit 1.15: MN Correlation Matrix for Stage of Technological Innovation and TI as Measurement Technology in Buildings and Construction

Stage of Technological Innovation	TI as Measurement Technology
Applied Research	4
Production	
Market	2
End-use	1

Exhibit 1.16: MN Correlation Matrix for TI as Measurement Technology and Measurement Barriers in Buildings and Construction

Innovation Equivalency	Measurement Solution Barriers															
	Acceptability/Compatibility	Accessibility	Accuracy	Data, Data Collection and/or Retrieval	Destructive	Expense	Lack of fundamental knowledge	Multiple Solutions Exist	Not Standardized	Production Readiness	Reliability	Resolution	Small Market Demand	Speed	System-Level Problem	Workforce
Technology Innovation = Measurement Innovation			1	5		1	1	1	4		1	1		1	1	

Exhibit 1.17: MN Correlation Matrix for Solution Providers and TI as Measurement Technology in Buildings and Construction

Measurement Solution Providers	Technology Innovation = Measurement Innovation
Calibration laboratories	
Commercial calibration service providers	
Component suppliers	
Contractor R&D labs-for-hire	
Engineering management/consulting firms/A&E firms	
Government laboratories and agencies	3
Independent testing/certification laboratories	1
Industrial R&D laboratories	
Industry consortium/partnership	2
Instrument suppliers	2
Material suppliers	
National Measurement Institute	6
Small business/inventors	
Software developers	
Standards development organizations (SDOs)	3
Testing laboratories	
Universities	1

Exhibit 1.18: MN Correlation Matrix for TI as Measurement Technology and Measurement Solutions in Buildings and Construction

	Measurement Solutions																								
	Infrastructure								Products														Services			
Innovation Equivalency	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Technology Innovation = Measurement Innovation		1	1		2	2	3			2	2	1	1	1	1				1	2					

Exhibit 1.19: MN Correlation Matrix for Regulation as Driver/Barrier and Measurement Solutions in Buildings and Construction

	Measurement Solutions																									
	Infrastructure								Products														Services			
Regulatory Issues	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Regulation is a Driver						1				1	1														
Regulation is a Barrier		2								2			1		1										

Exhibit 1.20: MN Correlation Matrix for Solution Providers and Regulation as Driver/Barrier in Buildings and Construction

Measurement Solution Providers	Regulation is a Driver	Regulation is a Barrier
Calibration laboratories		
Commercial calibration service providers		
Component suppliers		
Contractor R&D labs-for-hire		
Engineering management/consulting firms/A&E firms		
Government laboratories and agencies		2
Independent testing/certification laboratories	1	1
Industrial R&D laboratories		
Industry consortium/partnership		
Instrument suppliers		
Material suppliers		
National Measurement Institute	1	1
Small business/inventors		
Software developers		
Standards development organizations (SDOs)		
Testing laboratories		
Universities		1

U.S. Measurement System

Measurement Need (MN) Data Book

Chapter 2. Chemicals, Industrial Biotechnology, and Continuous Manufacturing

Prepared by
Energetics Incorporated
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National Institute of Standards and Technology

April 2006

Reference List of MN Distribution Charts and MN Correlation Matrices

Exhibit 2.1: MN Distribution of Measurement Barriers in Chemicals, Industrial Biotech, and Continuous Mfg

Acceptibility	Accessibility	Accuracy	Data, Data Collection & Retrieval	Destructive	Expense	Lack of Fundamental Knowledge	Multiple Solutions	Not Standardized	Production Readiness	Reliability	Resolution	Small market demand	Speed	Systems-level	Workforce	Total
3	2	10	13	1	3	7	2	4	1	6	4	0	3	1	0	60

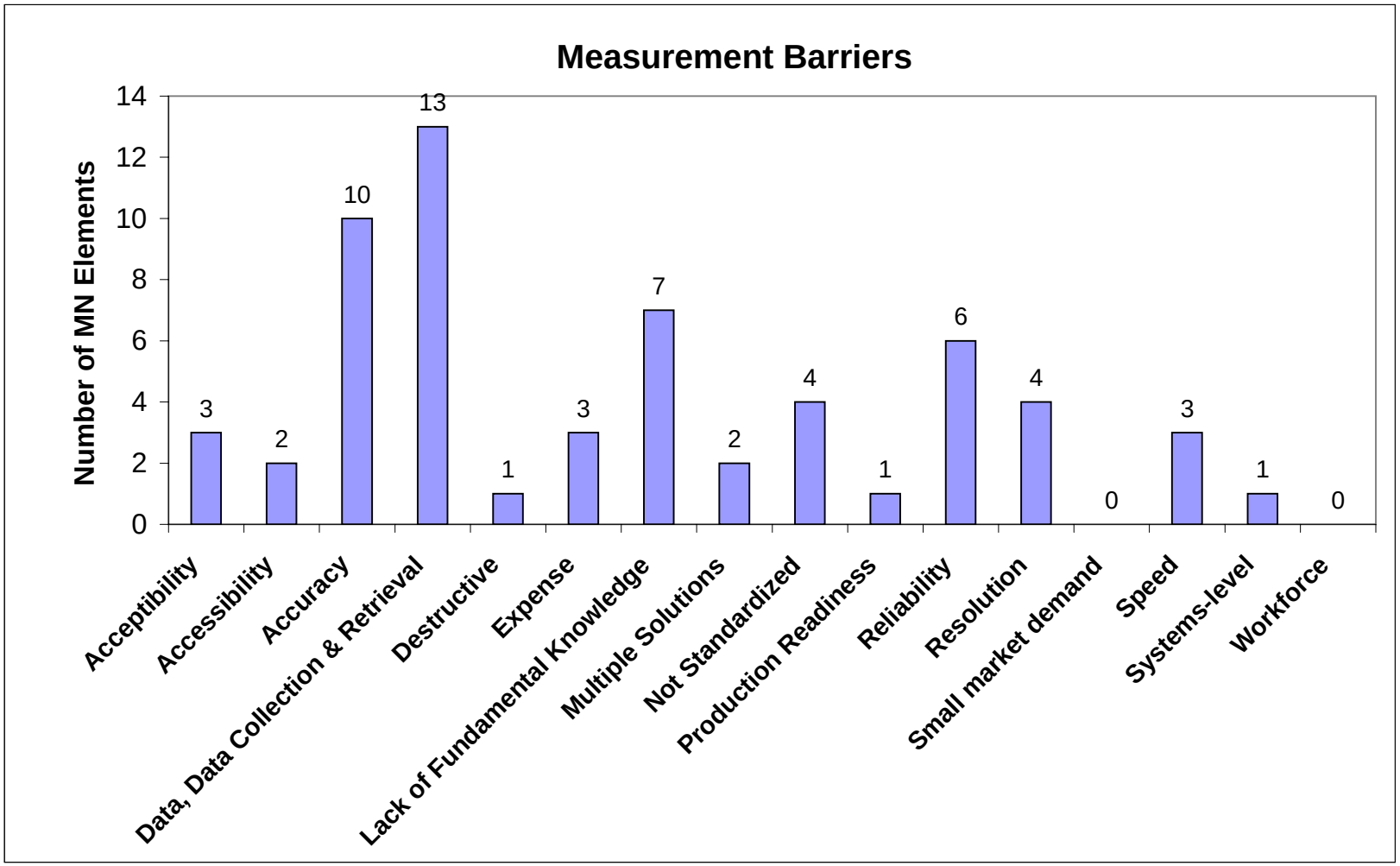

Exhibit 2.2: MN Distribution of Measurement Solution Providers in Chemicals, Industrial Biotech, and Continuous Mfg

Calibration Laboratories	Commercial Calibration Service Providers	Component Suppliers	Contractor R&D Labs-for-Hire	Engineering Management/Consulting Firms/A&E Firms	Government Laboratories and Agencies	Independent Testing/Certification Laboratories	Industrial R&D Laboratories	Industry Consortium/ Partnership	Instrument Suppliers	Material Suppliers	National Measurement Institute	Small Business/Inventors	Software Developers	Standards Development Organizations (SDO)	Testing Laboratories	Universities	Total
0	0	1	0	1	12	1	2	6	7	1	16	0	3	3	0	8	61

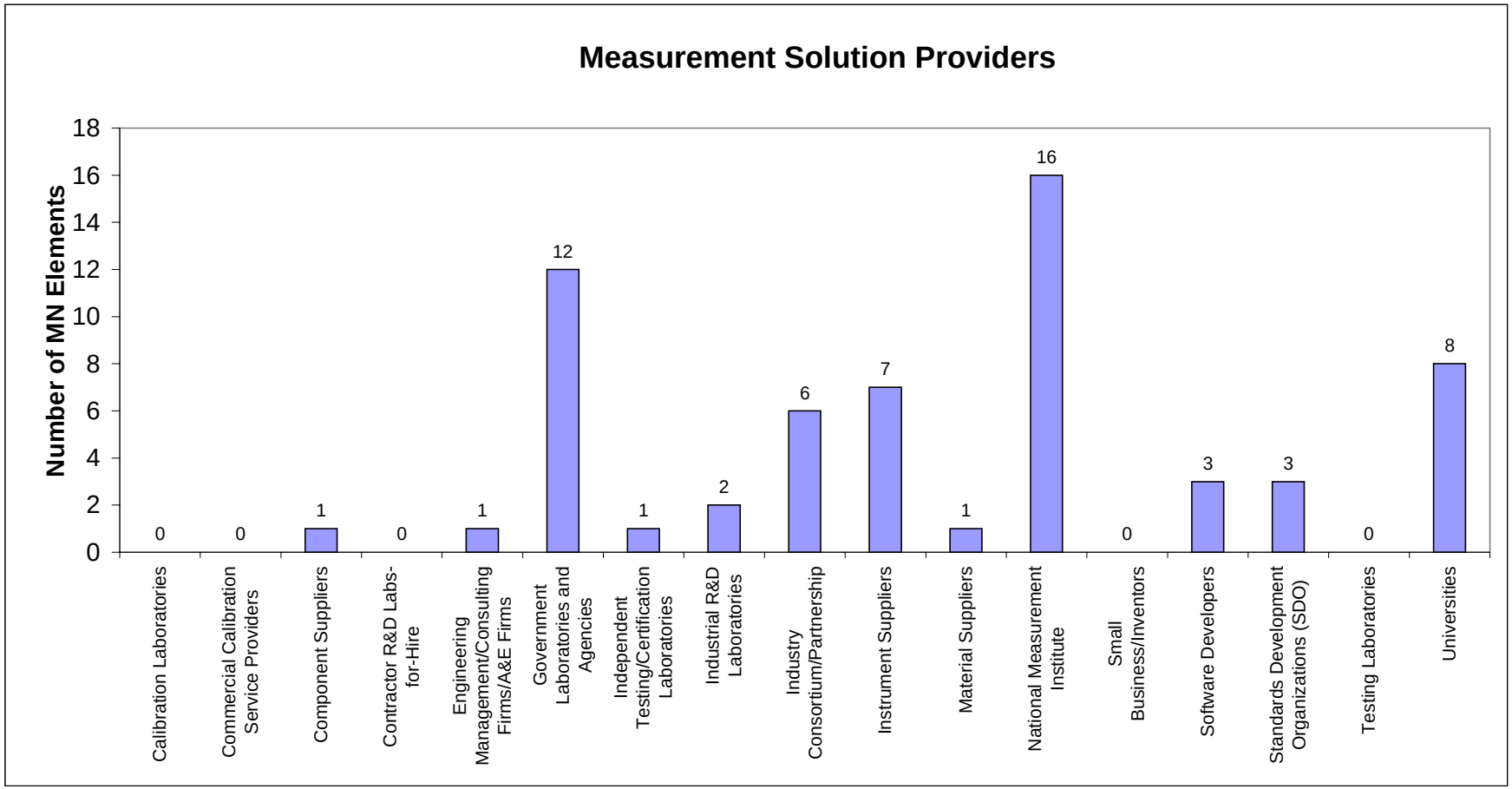

Exhibit 2.3: MN Distribution of Measurement Solutions in Chemicals, Industrial Biotech, and Continuous Mfg

Infrastructure								Products													Services				
Coordination/Facilitation	Data Collection/Retrieval	Development - Measurement Technology	Fund-amental Knowledge	Protocols	Research - Measure-ment Science	Standards	User Facility	Calibration	Computational Methods	Measure-ment Instrument	Measure-ment Method	Metrics/Benchmarks	Raw Data	Reference Data	Software	Stability Tests	Standard/certified reference material	Test methods for production-scale measurements	Test methods or test data for consumer products	Validated (hardened) properties data	Calibration	Expert consultation	Intl Recognition	Third Party Verification	Total
2	3	7	4	1	4	8	3	4	3	5	7	0	0	3	1	0	2	1	2	0	0	0	0	2	62

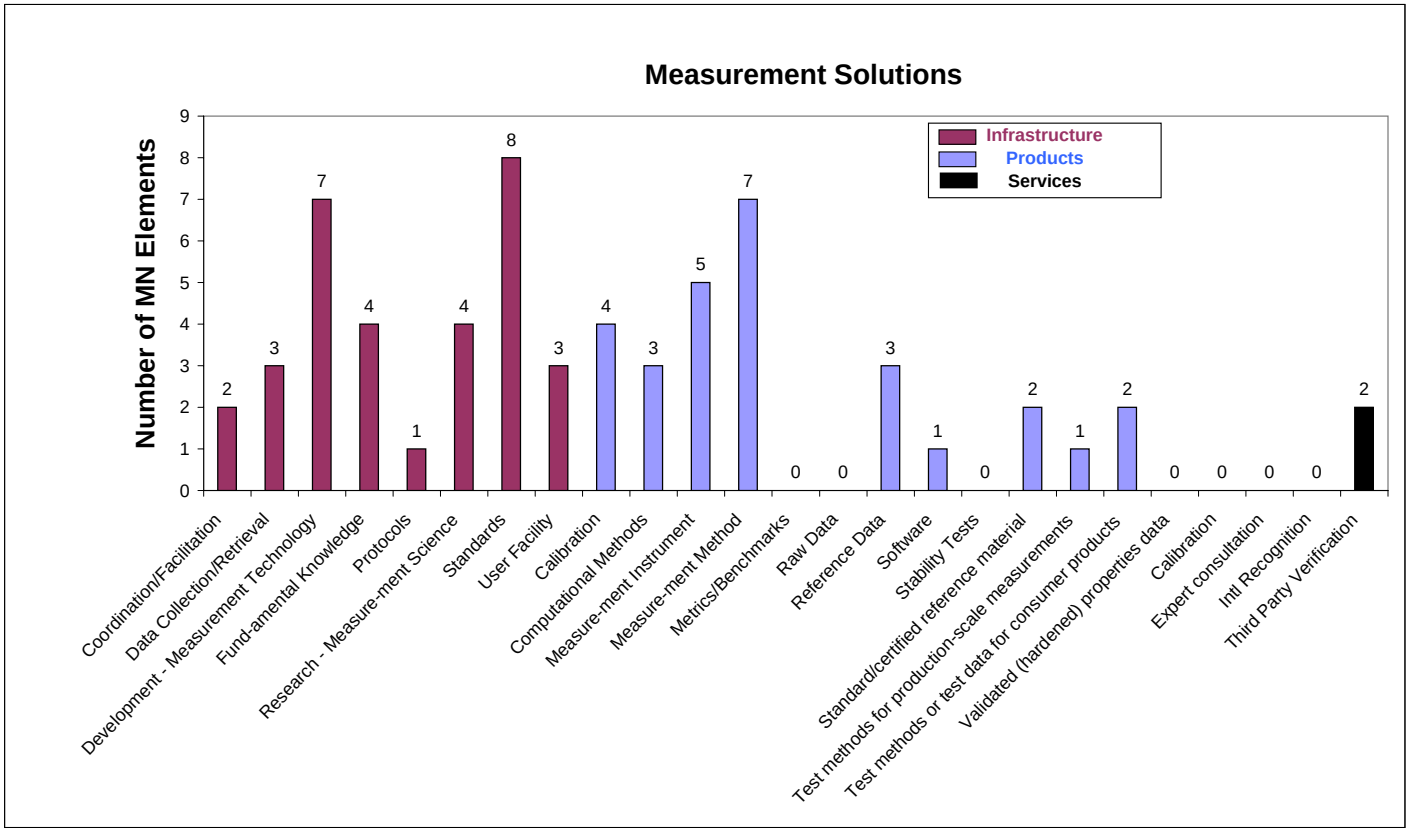

Exhibit 2.4: MN Distribution of Measurands in Chemicals, Industrial Biotech, and Continuous Mfg

Classical				Functional									Performance			Structural				
Biological	Chemical	Physical	Physiological	Acoustical	Electronic/ Electrical	Magnetic	Optical	Photonic	Radio frequency	Thermal- Thermochemical	Thermal- Thermodynamic	Thermal- Thermophysical	Computational Performance	Software Performance	System Performance	Kinetic	Mechanical	Molecular	Spatial	Total
4	5	2	0	0	1	1	2	0	0	0	1	2	1	1	0	0	2	0	0	22

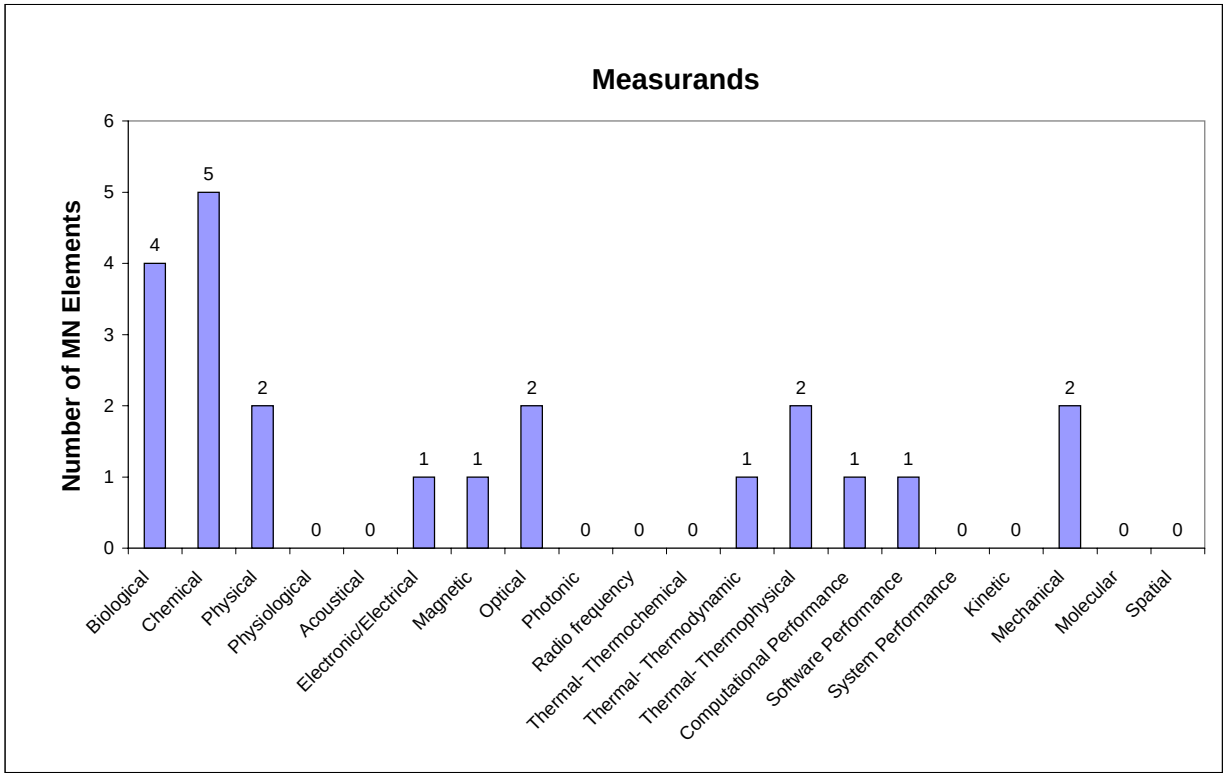

Exhibit 2.5: MN Distribution of Current Public/Private R&D Efforts in Chemicals, Industrial Biotech, and Continuous Mfg

Only Private Efforts Exist	Only Public Efforts Exist	Both Public and Private Efforts Exist	No Efforts Exist
1	3	5	13

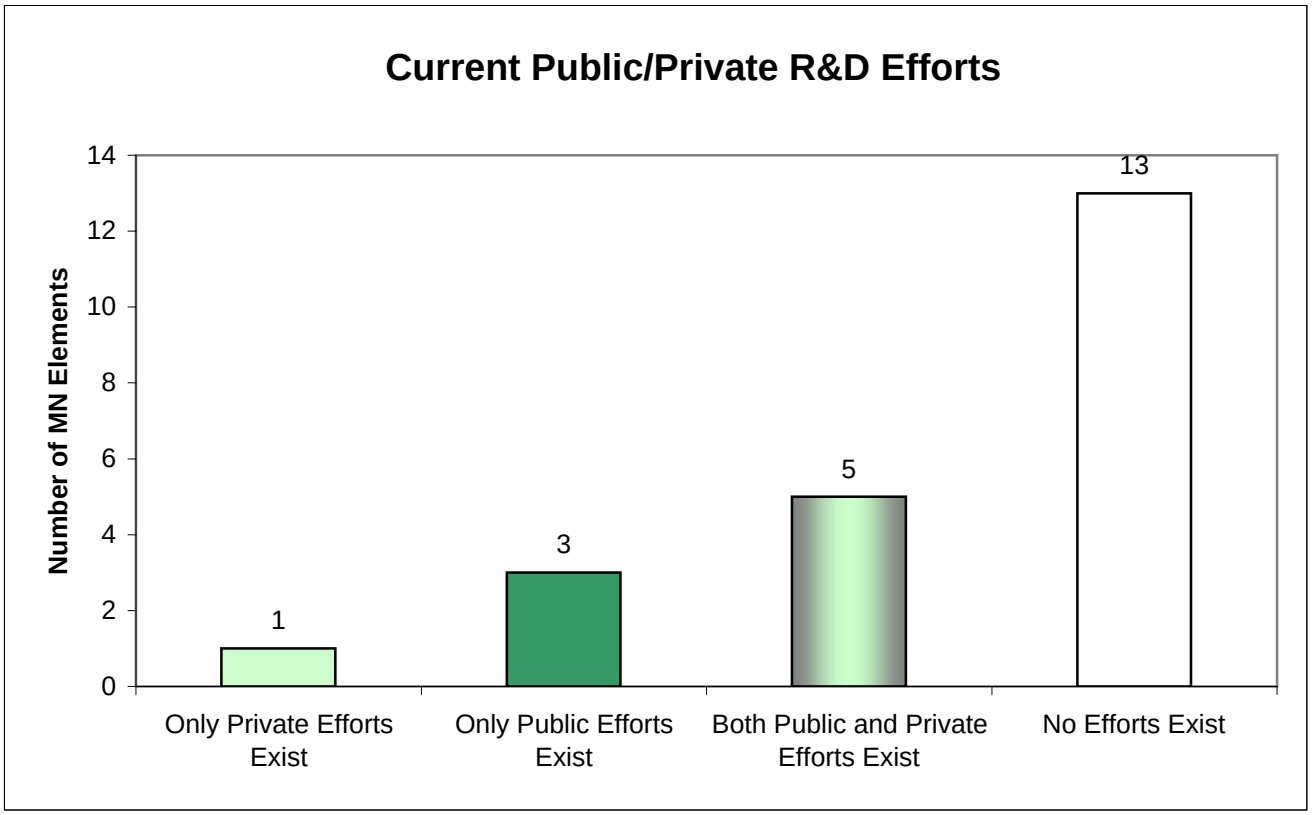

Exhibit 2.6: MN Distribution of TI as Measurement Technology in Chemicals, Industrial Biotech, and Continuous Mfg

Technology Innovation is a Measurement Innovation	Technology Innovation is not a Measurement Innovation
11	11

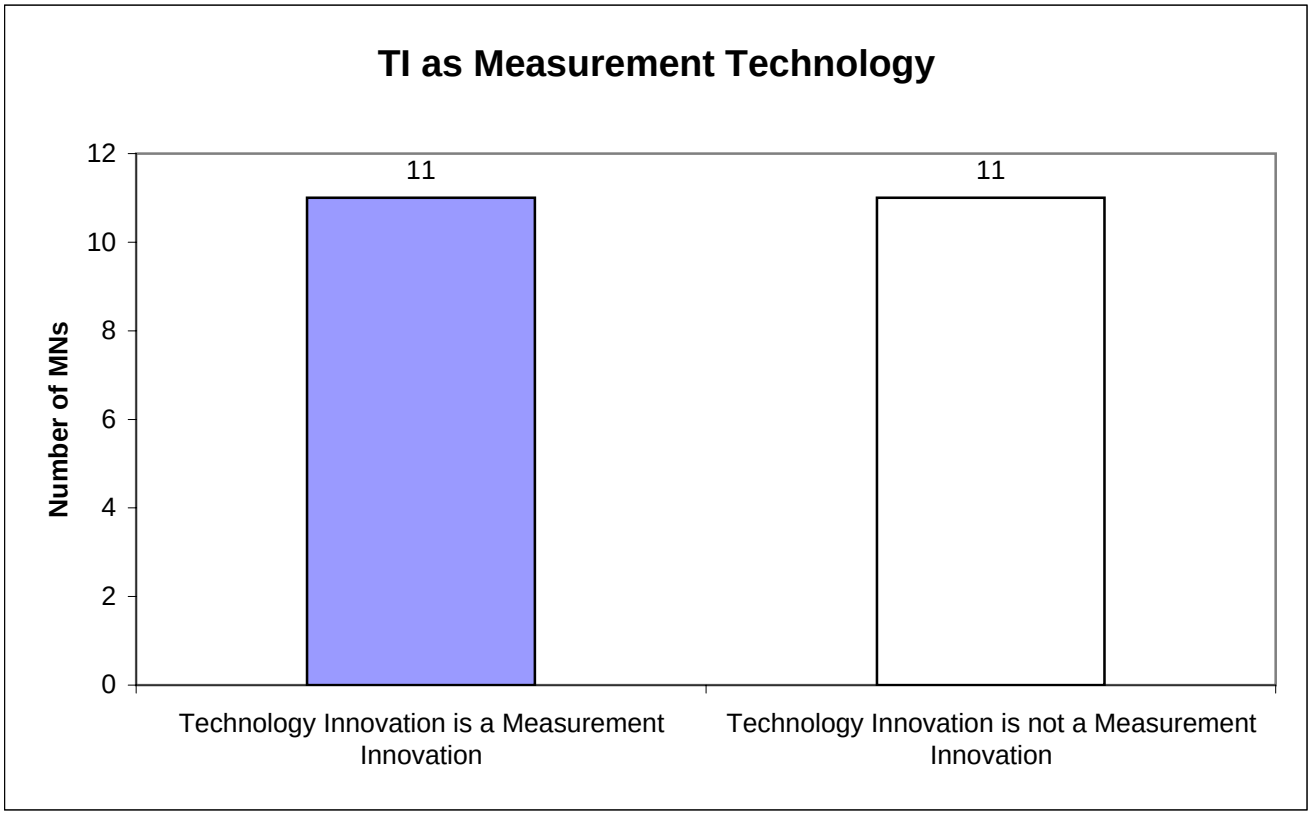

Exhibit 2.7: MN Distribution by Stage of Technological Innovation in Chemicals, Industrial Biotech, and Continuous Mfg

Applied Research	Production	Market	End-use	Total
15	5	2	0	22

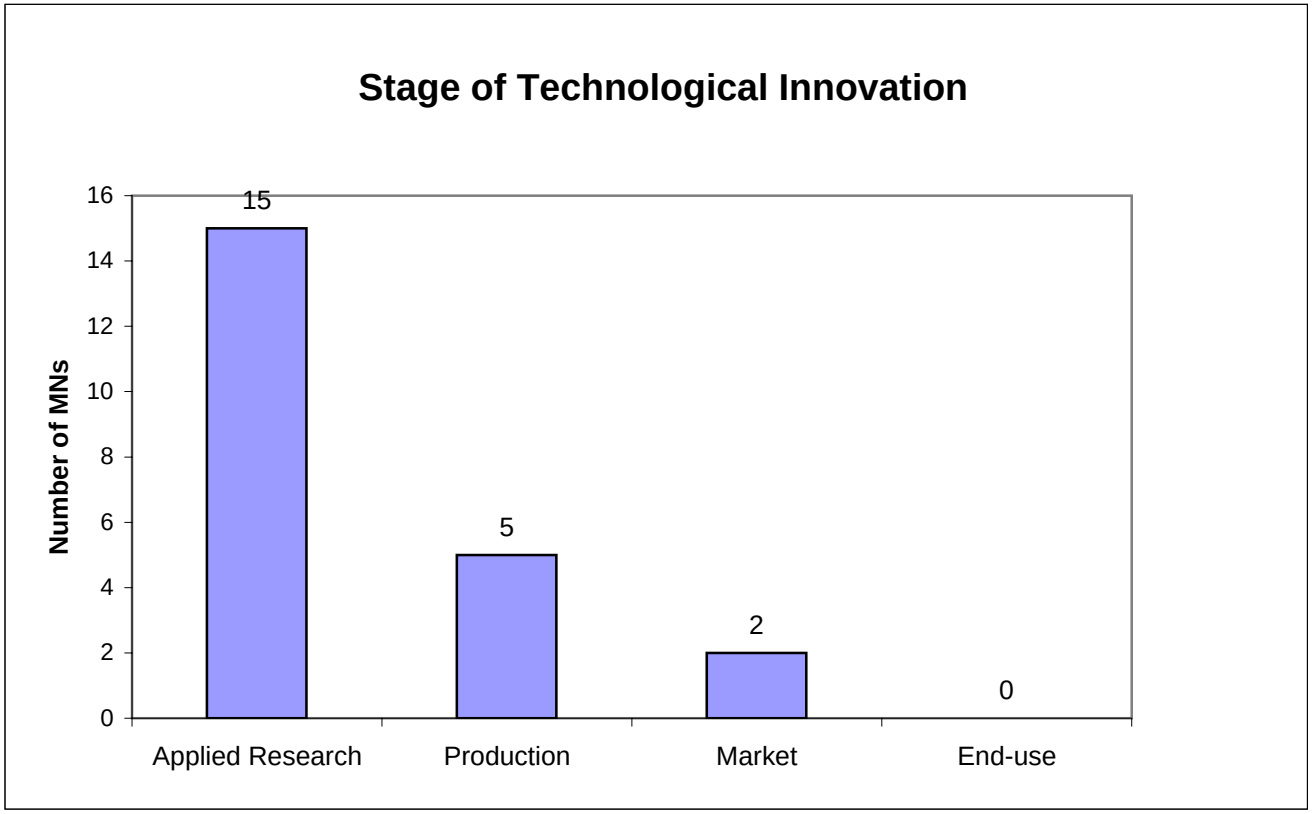

Exhibit 2.8: MN Distribution by Regulation as Driver/Barrier in Chemicals, Industrial Biotech, and Continuous Mfg

MN Driver	MN Barrier	No Impact
1	0	21

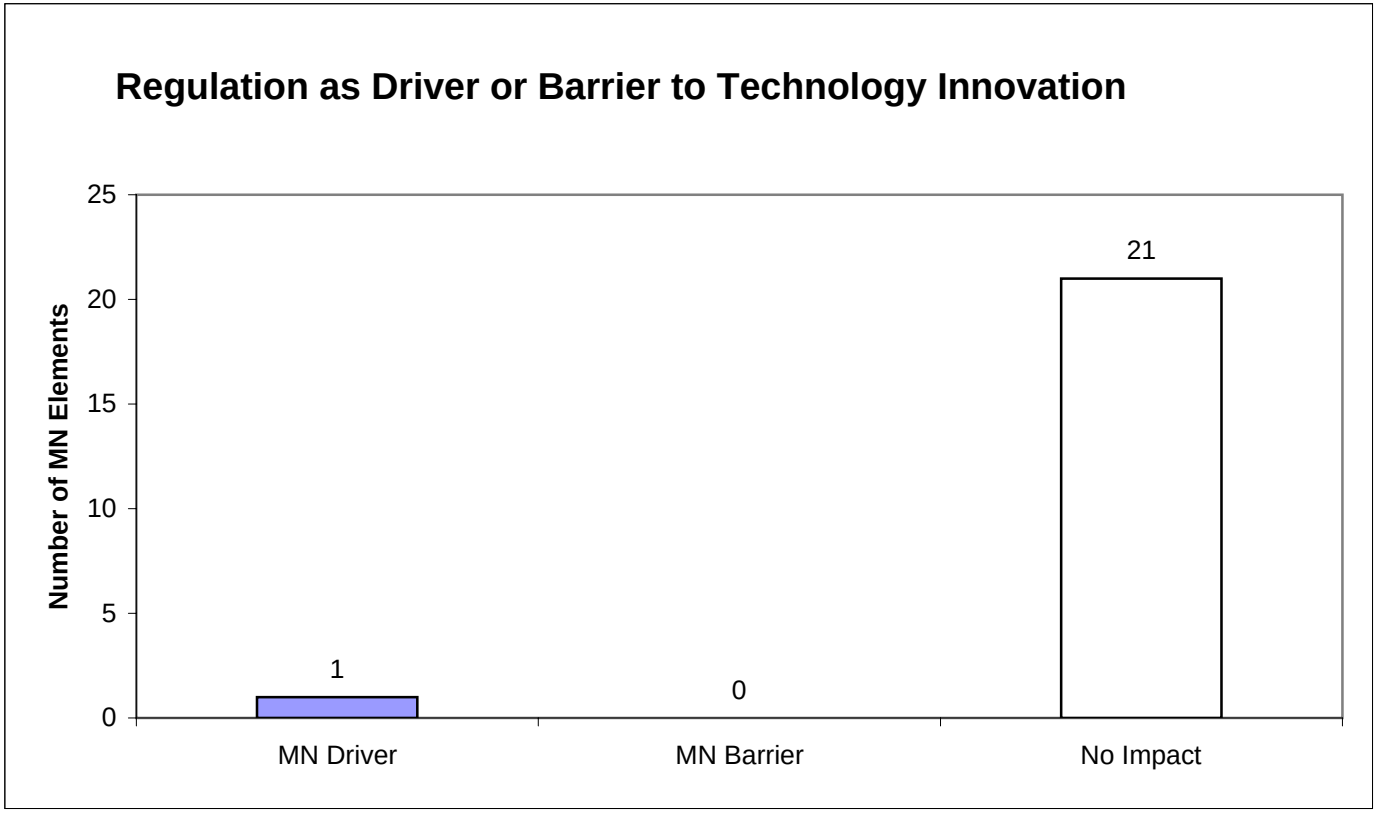

Exhibit 2.9: MN Correlation Matrix for Solution Providers and Measurement Barriers in Chemicals, Industrial Biotech, and Continuous Mfg

Solution Providers	Measurement Solution Barriers															
	Acceptability/Compatibility	Accessibility	Accuracy	Data, Data Collection and/or Retrieval	Destructive	Expense	Lack of fundamental knowledge	Multiple Solutions Exist	Not Standardized	Production Readiness	Reliability	Resolution	Small Market Demand	Speed	System-Level Problem	Workforce
Calibration laboratories																
Commercial calibration service providers																
Component suppliers			1					1			1					
Contractor R&D labs-for-hire																
Engineering management/consulting firms/A&E firms				1							1				1	
Government laboratories and agencies	1	1	6	6	1	2	3	1	1	1	2	3		3		
Independent testing/certification laboratories	1			1					1							
Industrial R&D laboratories			2					1			1					
Industry consortium/partnership	1	1	2	3		2	2		1		1			2		
Instrument suppliers	2		4	4		1	3		3	1		3				
Material suppliers			1				1		1							
National Measurement Institute	3	2	6	10	1	2	6	2	4		3	3		2	1	
Small business/inventors																
Software developers		1	1	3			1				2					
Standards development organizations (SDOs)			1	2	1		1				2			1		
Testing laboratories																
Universities		1	3	5		1	3	1	1	1	2	2		1		

Exhibit 2.10: MN Correlation Matrix for Measurement Barriers and Measurement Solutions in Chemicals, Industrial Biotech, and Continuous Mfg

	Measurement Solutions																								
	Infrastructure								Products													Services			
Measurement Solution Barriers	**Coordination/ facilitation**	**Data Collection/ Retrieval**	**Development for Measurement Technology**	**Fundamental Scientific Knowledge**	**Protocols**	**Research for Measurement Science**	**Standards**	**User Facility**	**Calibration Method**	**Computation Method**	**Measurement Instrument**	**Measurement Method**	**Metrics/ Benchmarks**	**Raw Properties Data**	**Reference Data**	**Software**	**Stability Tests**	**Standard/CRM**	**Test Methods - Production Scale**	**Test Methods - Consumer Products**	**Validated Data**	**Calibration Services**	**Expert Consultation**	**International Recognition**	**3rd Party Verification**
Acceptability/Compatibility							1	1	1			1			1				1	2					1
Accessibility		1					1			1	1	1			1										
Accuracy	1	1	5		1	3	3	3	3	1	3							1	1						
Data, Data Collection/and or Retrieval	2	3	3	3	1		4	2	2	3	3	4			3	1		1		2					2
Destructive							1					1						1							
Expense			1			1	2	1	1		1	1							1						
Lack of Fundamental Knowledge		1	2	4		1	3		1	2	1	4			1			1							
Multiple Solutions Exist			2			1			1		1	1													
Not Standardized			2	1			2		1			2			1					2					1
Production Readiness			1																						
Reliability	2	2	1		1	1	2	1	1	1	2				1	1		1							1
Resolution			3	1				1	1		2	2													
Small Market Demand																									
Speed			1			1	3				1	2						1							
System-Level Problem	1	1														1									
Workforce																									

Exhibit 2.11: MN Correlation Matrix for Measurement Providers and Measurement Solutions in Chemicals, Industrial Biotech, and Continuous Mfg

	Measurement Solutions																									
	Infrastructure								Products														Services			
Measurement Solution Providers	**Coordination/ facilitation**	**Data Collection/ Retrieval**	**Development for Measurement Technology**	**Fundamental Scientific Knowledge**	**Protocols**	**Research for Measurement Science**	**Standards**	**User Facility**	**Calibration Method**	**Computation Method**	**Measurement Instrument**	**Measurement Method**	**Metrics/ Benchmarks**	**Raw Properties Data**	**Reference Data**	**Software**	**Stability Tests**	**Standard/CRM**	**Test Methods - Production Scale**	**Test Methods - Consumer Products**	**Validated Data**	**Calibration Services**	**Expert Consultation**	**International Recognition**	**3rd Party Verification**
Calibration laboratories																										
Commercial calibration service providers																										
Component suppliers			1			1					1															
Contractor R&D labs-for-hire																										
Engineering management/consulting firms/A&E firms	1	1														1										
Government laboratories and agencies	1	1	4	2	1	3	5	1	1	2	3	4						2		1						1
Independent testing/certification laboratories												1			1					1						
Industrial R&D laboratories			1			2					1															
Industry consortium/partnership			1	2	1	2	3			1	2	3			1			1		1						
Instrument suppliers			4	2			2	2	2		2	2							1	1						1
Material suppliers			1				1		1																	
National Measurement Institute	1	2	5	3		2	6	3	4	2	4	6			2	1		1	1	2						1
Small business/inventors																										
Software developers	1	2					1			2					2											1
Standards development organizations (SDOs)					1		2				1	1			1			2								1
Testing laboratories																										
Universities	1	2	4	2		2	2		1	2		3			2											1

Exhibit 2.12: MN Correlation Matrix for Stage of Technological Innovation and Measurement Barriers in Chemicals, Industrial Biotech, and Continuous Mfg

Stage of Technological Innovation	Measurement Solution Barriers															
	Acceptability/Compatibility	Accessibility	Accuracy	Data, Data Collection and/or Retrieval	Destructive	Expense	Lack of fundamental knowledge	Multiple Solutions Exist	Not Standardized	Production Readiness	Reliability	Resolution	Small Market Demand	Speed	System-Level Problem	Workforce
Applied Research		2	6	9	1	2	6	2	1		4	3		3		
Production	2		3	2		1	1		2	1	1	1			1	
Market	1		1	2					1		1					
End-use																

Exhibit 2.13: MN Correlation Matrix for Stage of Technological Innovation and Measurement Solutions in Chemicals, Industrial Biotech, and Continuous Mfg

	Measurement Solutions																									
	Infrastructure								Products														Services			
Stage of Technological Innovation	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Applied Research	1	2	5	4		4	6	2	2	3	4	6			2			1							1
Production	1	1	2				1	1	2			1			1	1			1	1					
Market					1		1				1							1		1					1
End-use																									

Exhibit 2.14: MN Correlation Matrix for Solution Providers and Stage of Technological Innovation in Chemicals, Industrial Biotech, and Continuous Mfg

Measurement Solution Providers	Stage of Technological Innovation			
	Applied Research	Production	Market	End-use
Calibration laboratories				
Commercial calibration service providers				
Component suppliers	1			
Contractor R&D labs-for-hire				
Engineering management/consulting firms/A&E firms		1		
Government laboratories and agencies	9	1	2	
Independent testing/certification laboratories		1		
Industrial R&D laboratories	2			
Industry consortium/partnership	4	1	1	
Instrument suppliers	3	3	1	
Material suppliers		1		
National Measurement Institute	11	4	1	
Small business/inventors				
Software developers	3			
Standards development organizations (SDOs)	2		1	
Testing laboratories				
Universities	7	1		

Exhibit 2.15: MN Correlation Matrix for Stage of Technological Innovation and TI as Measurement Technology in Chemicals, Industrial Biotech, and Continuous Mfg

Stage of Technological Innovation	TI as Measurement Technology
Applied Research	9
Production	2
Market	
End-use	

Exhibit 2.16: MN Correlation Matrix for TI as Measurement Technology and Measurement Barriers in Chemicals, Industrial Biotech, and Continuous Mfg

	Measurement Solution Barriers															
Innovation Equivalency	**Acceptability/Compatibility**	**Accessibility**	**Accuracy**	**Data, Data Collection and/or Retrieval**	**Destructive**	**Expense**	**Lack of fundamental knowledge**	**Multiple Solutions Exist**	**Not Standardized**	**Production Readiness**	**Reliability**	**Resolution**	**Small Market Demand**	**Speed**	**System-Level Problem**	**Workforce**
Technology Innovation = Measurement Innovation		1	5	7			5	2	2		4	2			1	

Exhibit 2.17: MN Correlation Matrix for Solution Providers and TI as Measurement Technology in Chemicals, Industrial Biotech, and Continuous Mfg

Measurement Solution Providers	Technology Innovation = Measurement Innovation
Calibration laboratories	
Commercial calibration service providers	
Component suppliers	1
Contractor R&D labs-for-hire	
Engineering management/consulting firms/A&E firms	1
Government laboratories and agencies	4
Independent testing/certification laboratories	
Industrial R&D laboratories	2
Industry consortium/partnership	1
Instrument suppliers	3
Material suppliers	1
National Measurement Institute	9
Small business/inventors	
Software developers	2
Standards development organizations (SDOs)	
Testing laboratories	
Universities	5

Exhibit 2.18: MN Correlation Matrix for TI as Measurement Technology and Measurement Solutions in Chemicals, Industrial Biotech, and Continuous Mfg

	Measurement Solutions																								
	Infrastructure								Products													Services			
Innovation Equivalency	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Technology Innovation = Measurement Innovation	2	3	4	3		3	2	1	3	2	2	4			1	1									

Exhibit 2.19: MN Correlation Matrix for Regulation as Driver/Barrier and Measurement Solutions in Chemicals, Industrial Biotech, and Continuous Mfg

	Measurement Solutions																									
	Infrastructure								Products														Services			
Regulatory Issues	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Regulation is a Driver	1	1														1										
Regulation is a Barrier																										

Exhibit 2.20: MN Correlation Matrix for Solution Providers and Regulation as Driver/Barrier in Chemicals, Industrial Biotech, and Continuous Mfg

Measurement Solution Providers	Regulation is a Driver	Regulation is a Barrier
Calibration laboratories		
Commercial calibration service providers		
Component suppliers		
Contractor R&D labs-for-hire		
Engineering management/consulting firms/A&E firms	1	
Government laboratories and agencies		
Independent testing/certification laboratories		
Industrial R&D laboratories		
Industry consortium/partnership		
Instrument suppliers		
Material suppliers		
National Measurement Institute	1	
Small business/inventors		
Software developers		
Standards development organizations (SDOs)		
Testing laboratories		
Universities		

U.S. Measurement System

Measurement Need (MN) Data Book

Chapter 3. Defense and Homeland Security

(includes First Responders)

Prepared by
Energetics Incorporated
for the
National Institute of Standards and Technology

April 2006

Reference List of MN Distribution Charts and MN Correlation Matrices

Distribution Charts **Page**

Exhibit Number

Correlation Matrices

Exhibit Number

Exhibit 3.1: MN Distribution of Measurement Barriers in Defense and Homeland Security

Acceptibility	Accessibility	Accuracy	Data, Data Collection & Retrieval	Destructive	Expense	Lack of Fundamental Knowledge	Multiple Solutions	Not Standardized	Production Readiness	Reliability	Resolution	Small market demand	Speed	Systems-level	Workforce	Total
5	1	18	12	1	3	10	0	17	1	11	4	1	3	0	0	87

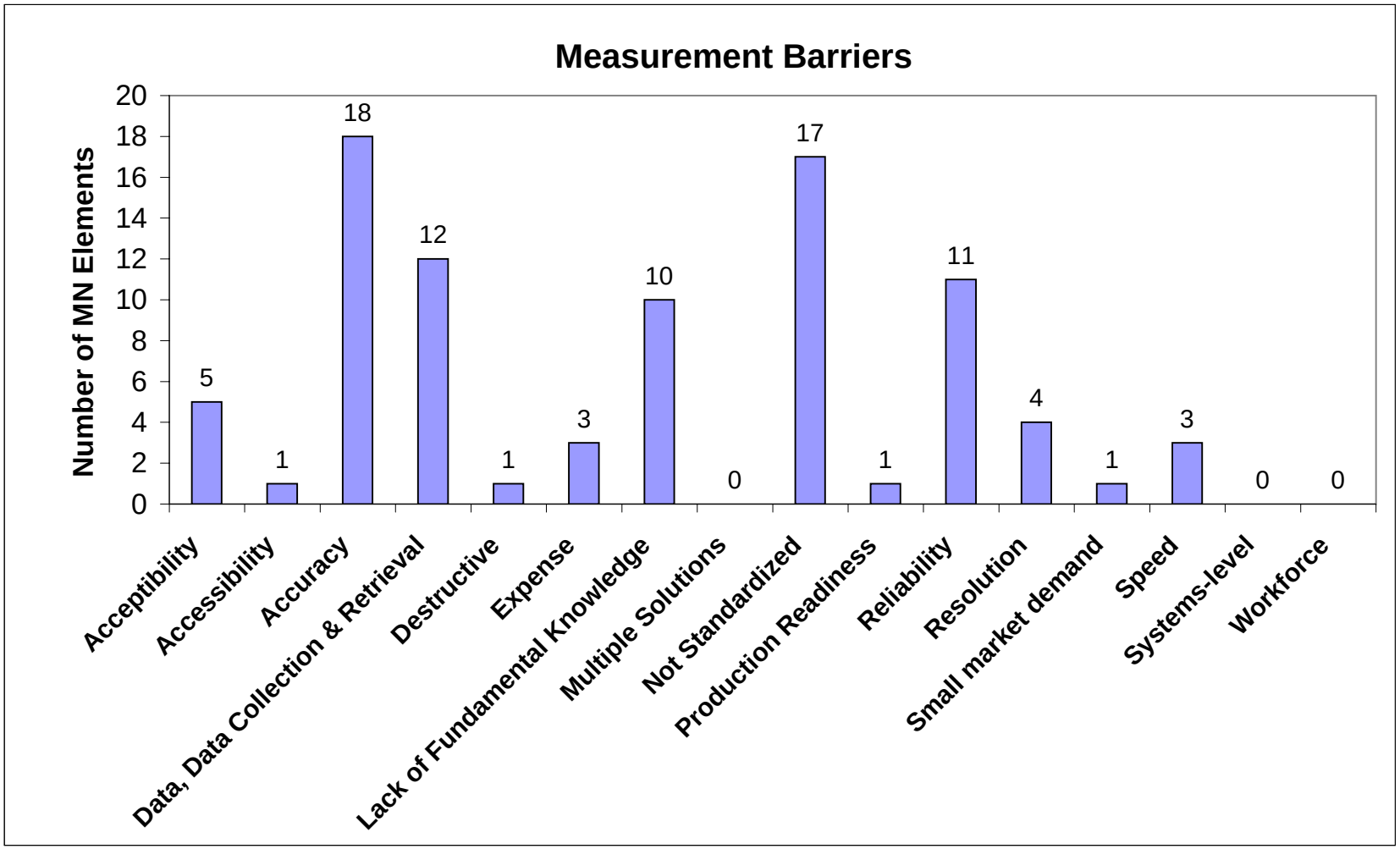

Exhibit 3.2: MN Distribution of Measurement Solution Providers in Defense and Homeland Security

Calibration Laboratories	Commercial Calibration Service Providers	Component Suppliers	Contractor R&D Labs-for-Hire	Engineering Management/Consulting Firms/A&E Firms	Government Laboratories and Agencies	Independent Testing/Certification Laboratories	Industrial R&D Laboratories	Industry Consortium/ Partnership	Instrument Suppliers	Material Suppliers	National Measurement Institute	Small Business/Inventors	Software Developers	Standards Development Organizations (SDO)	Testing Laboratories	Universities	Total
0	1	1	2	1	23	0	6	3	12	1	30	0	2	5	0	8	95

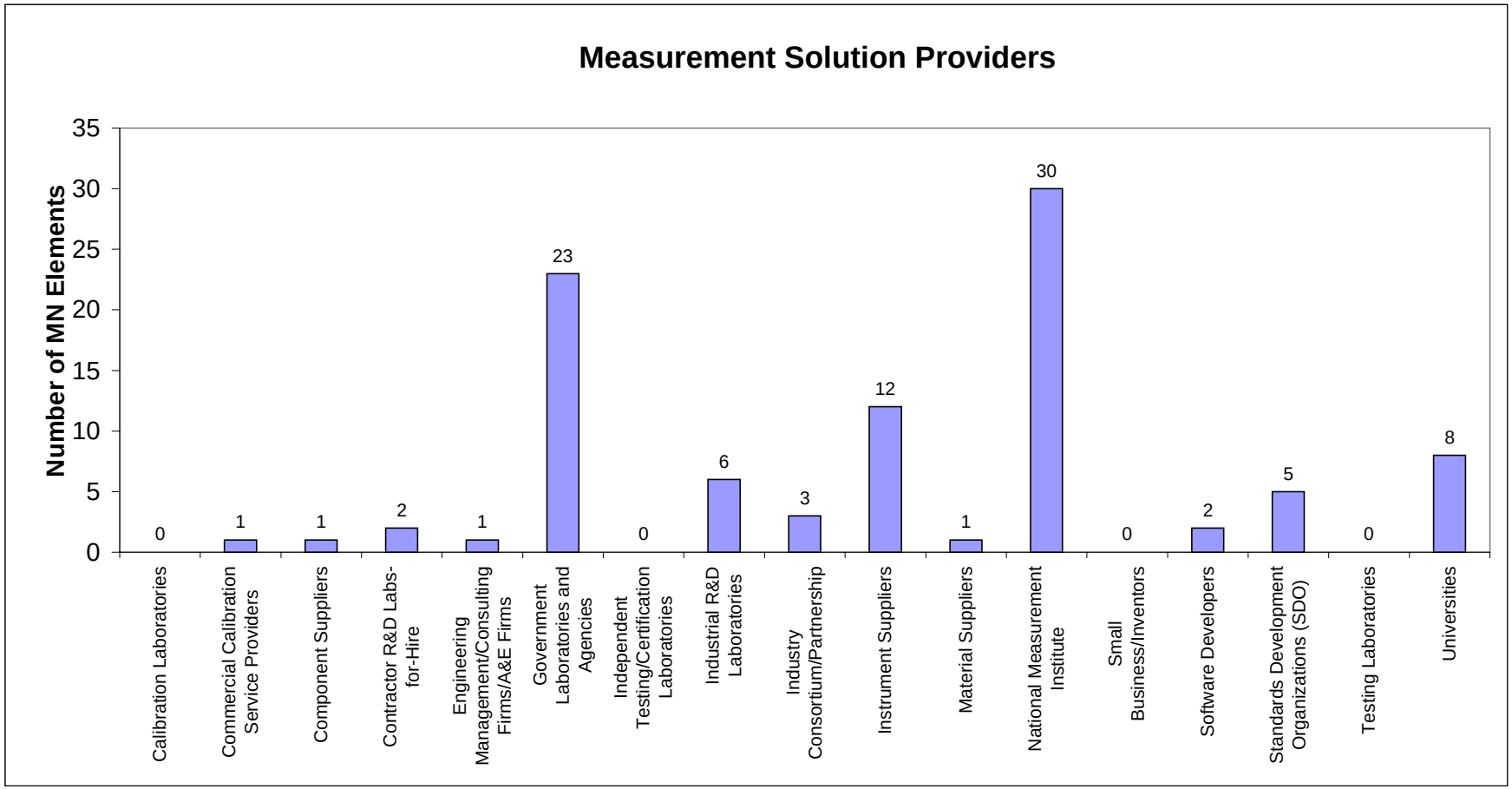

Exhibit 3.3: MN Distribution of Measurement Solutions in Defense and Homeland Security

Infrastructure								Products												Services				
Coordination/Facilitation	Data Collection/Retrieval	Devolpment - Measurement Technology	Fund-amental Knowledge	Protocols	Research - Measure-ment Science	Standards	User Facility	Calibration	Computational Methods	Measure-ment Instrument	Measure-ment Method	Metrics/Benchmarks	Raw Data	Reference Data	Software	Stability Tests	Standard/certified reference material	Test methods for production-scale measurements	Test methods or test data for consumer products	Validated (hardened) properties data	Calibration	Expert consultation	Intl Recognition	Third Party Verification	Total
0	2	7	4	4	3	8	2	6	4	8	11	7	3	4	0	1	4	3	6	1	0	1	0	2	91

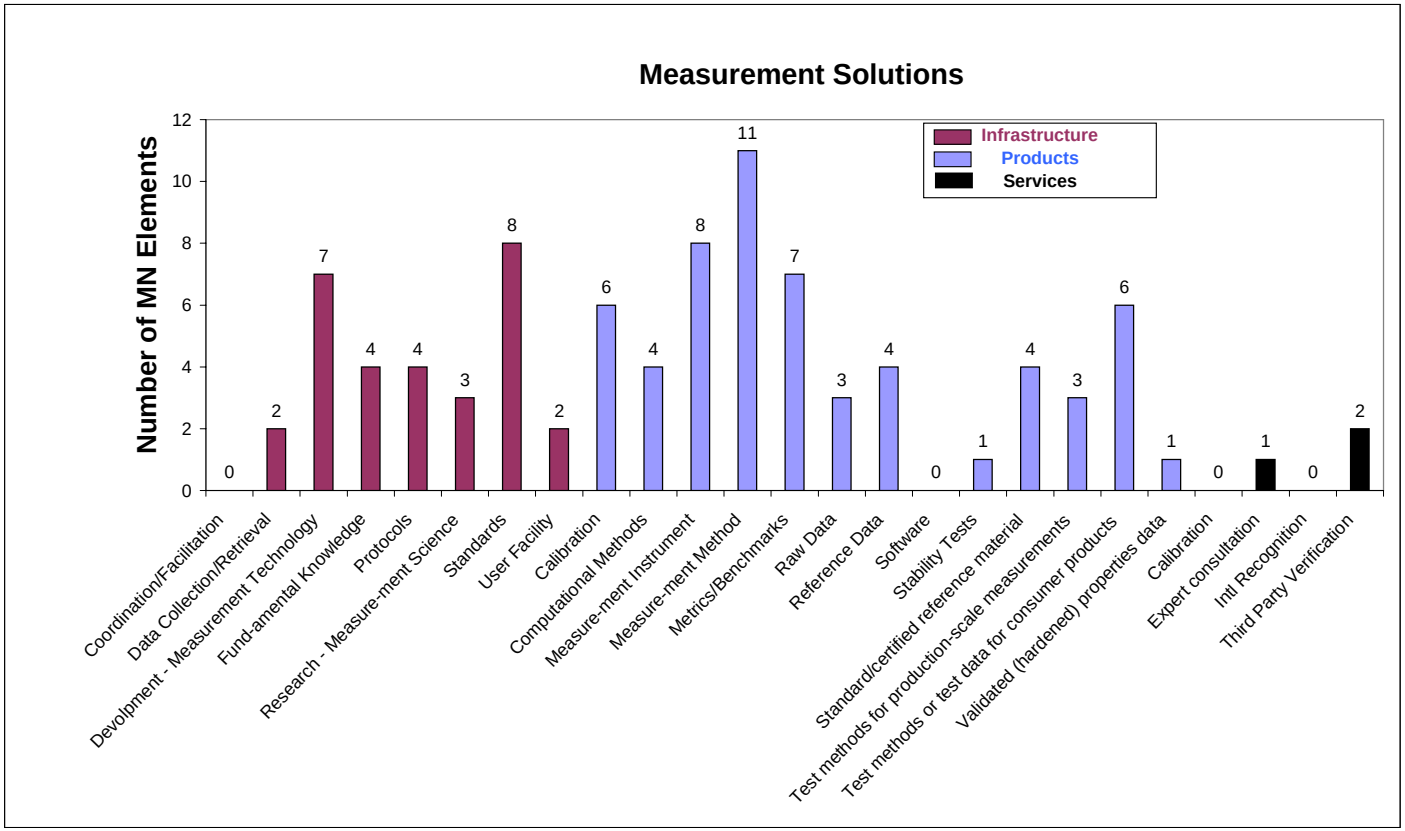

Exhibit 3.4: MN Distribution of Measurands in Defense and Homeland Security

Classical				Functional									Performance			Structural				
Biological	Chemical	Physical	Physiological	Acoustical	Electronic/ Electrical	Magnetic	Optical	Photonic	Radio frequency	Thermal- Thermochemical	Thermal- Thermodynamic	Thermal- Thermophysical	Computational Performance	Software Performance	System Performance	Kinetic	Mechanical	Molecular	Spatial	Total
1	2	6	0	2	1	3	3	2	2	0	0	1	0	0	8	1	1	0	1	34

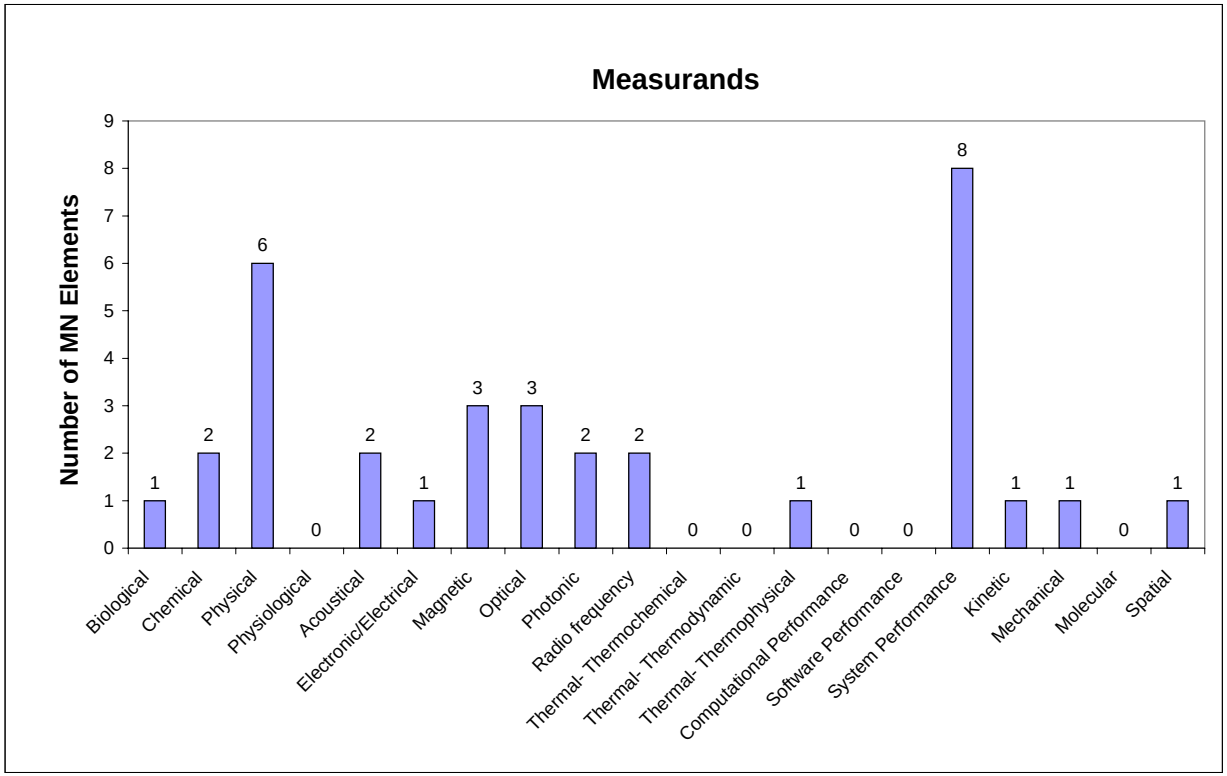

Exhibit 3.5: MN Distribution of Current Public/Private R&D Efforts in Defense and Homeland Security

Only Private Efforts Exist	Only Public Efforts Exist	Both Public and Private Efforts Exist	No Efforts Exist
3	7	5	19

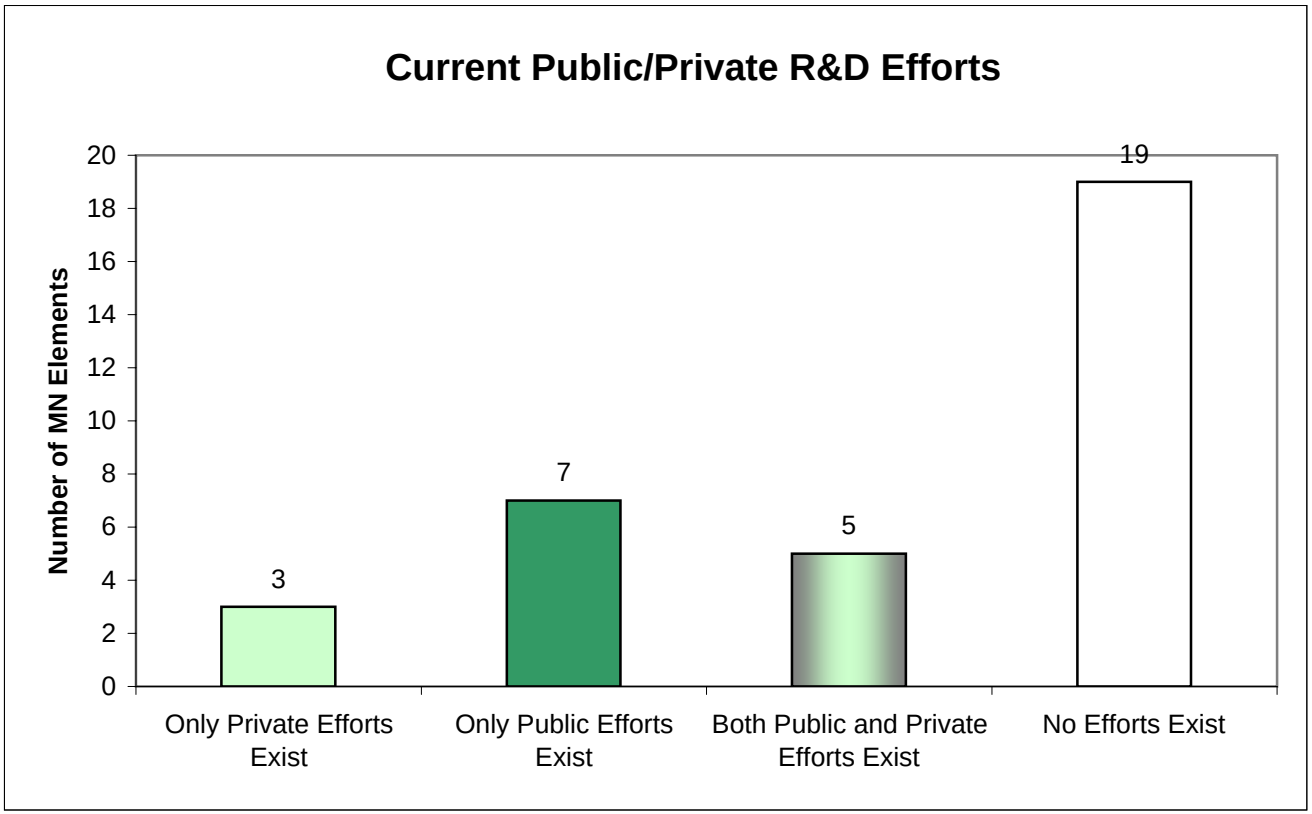

Exhibit 3.6: MN Distribution of TI as Measurement Technology in Defense and Homeland Security

Technology Innovation is a Measurement Innovation	Technology Innovation is not a Measurement Innovation
19	15

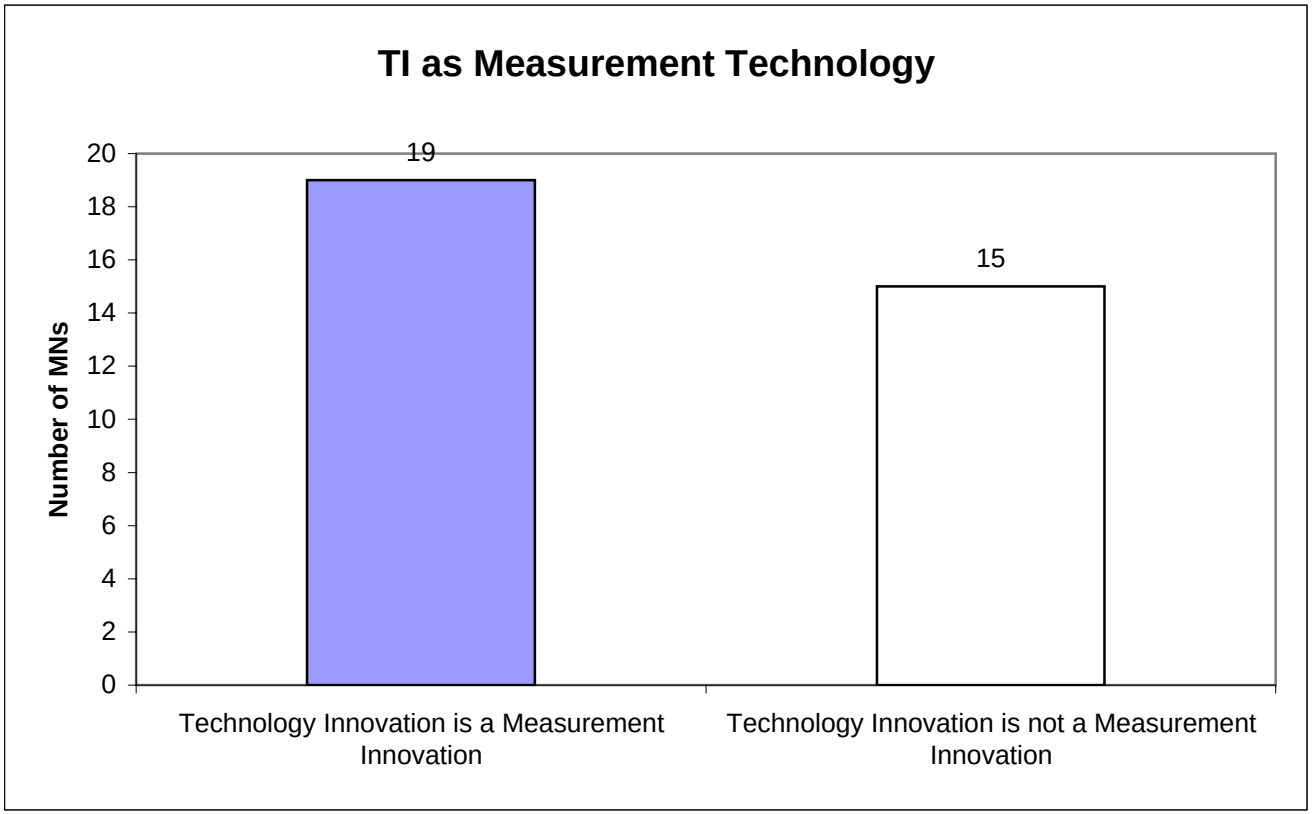

Exhibit 3.7: MN Distribution by Stage of Technological Innovation in Defense and Homeland Security

Applied Research	Production	Market	End-use	Total
27	2	3	2	34

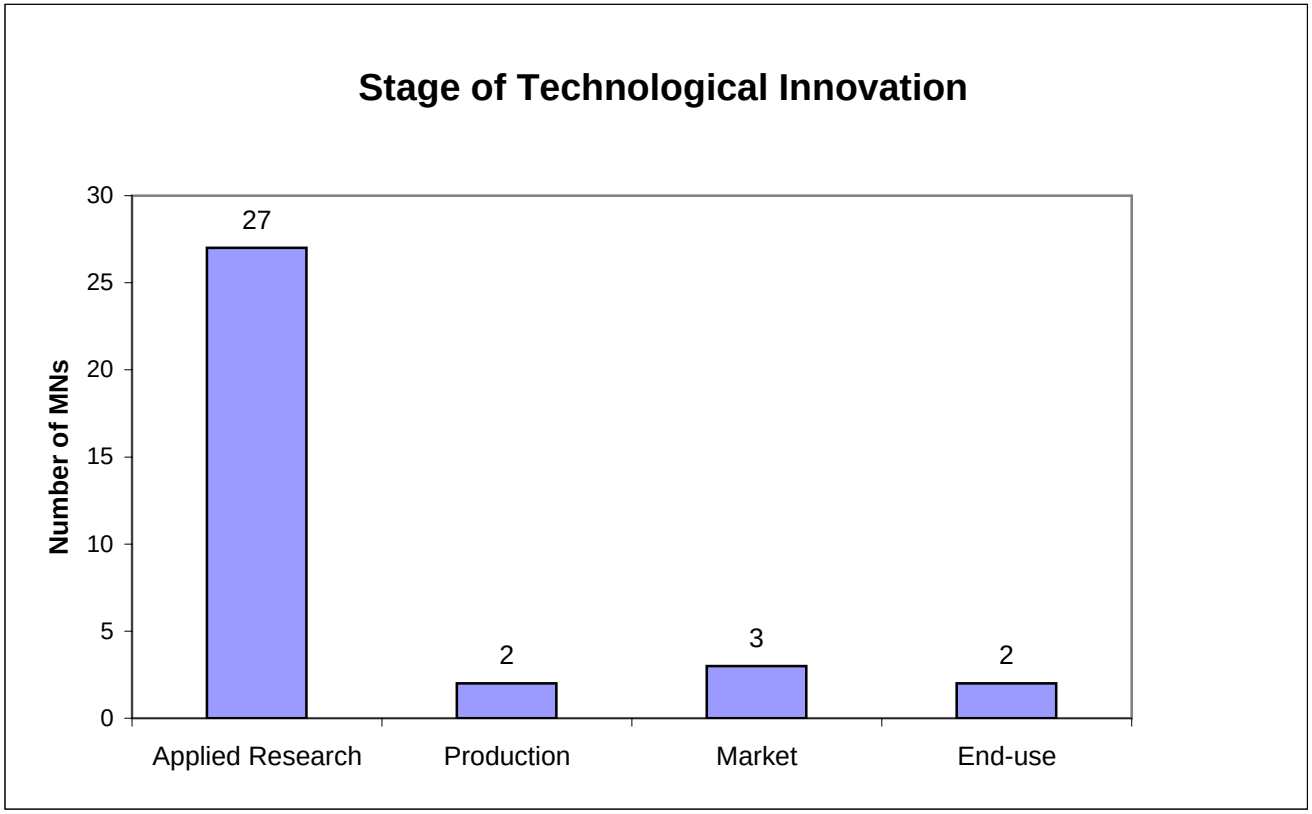

Exhibit 3.8: MN Distribution of Regulation as Driver/Barrier in Defense and Homeland Security

MN Driver	MN Barrier	No Impact
3	1	30

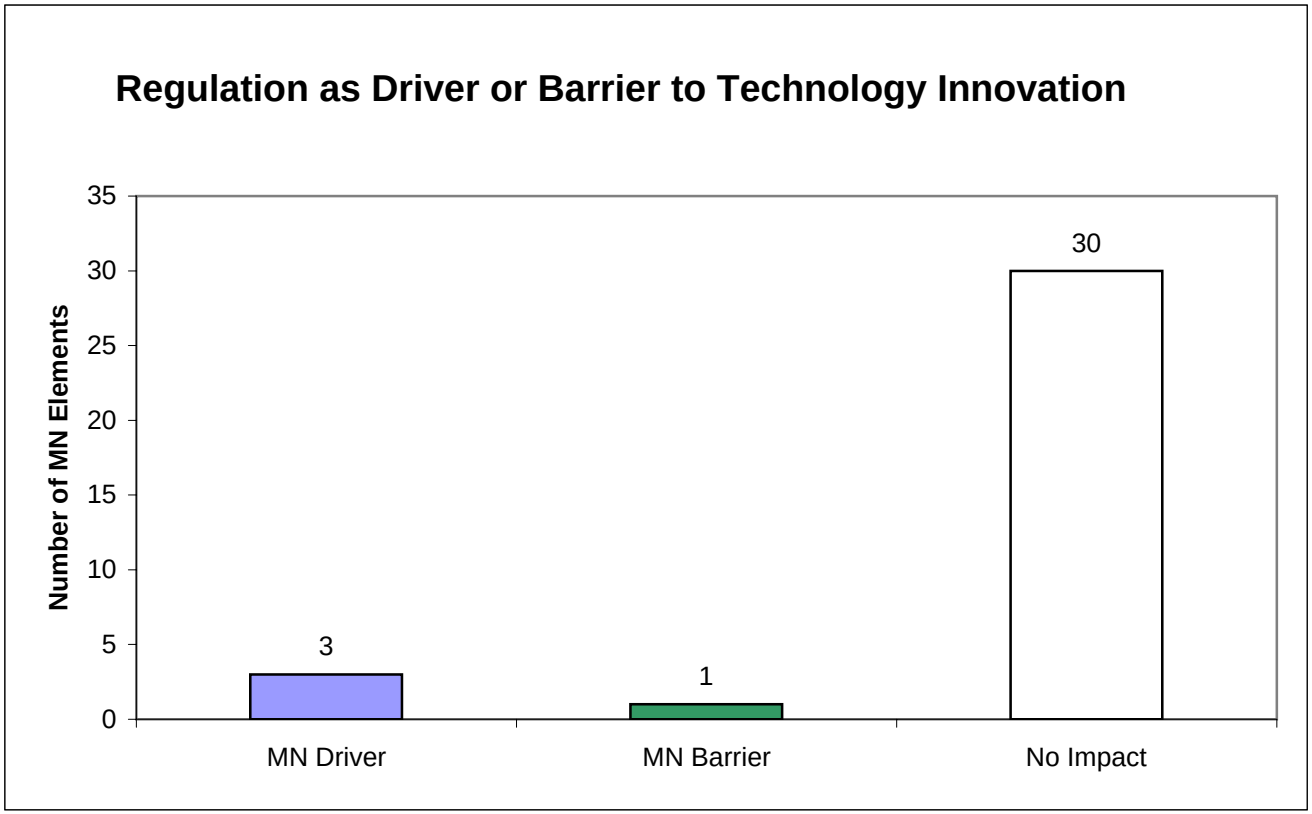

Exhibit 3.9: MN Correlation Matrix for Solution Providers and Measurement Barriers in Defense and Homeland Security

Solution Providers	Measurement Solution Barriers															
	Acceptability/Compatibility	Accessibility	Accuracy	Data, Data Collection and/or Retrieval	Destructive	Expense	Lack of fundamental knowledge	Multiple Solutions Exist	Not Standardized	Production Readiness	Reliability	Resolution	Small Market Demand	Speed	System-Level Problem	Workforce
Calibration laboratories																
Commercial calibration service providers				1					1							
Component suppliers			1				1		1							
Contractor R&D labs-for-hire	1		2	1					1		1					
Engineering management/consulting firms/A&E firms									1							
Government laboratories and agencies	2		10	9	1	1	7		12	1	8	3		2		
Independent testing/certification laboratories																
Industrial R&D laboratories	1		3		1		2		2		3	1		1		
Industry consortium/partnership	1		1	1			2		3				1			
Instrument suppliers	3	1	7	4		1	4		6	1	4	3	1			
Material suppliers			1				1		1							
National Measurement Institute	4	1	16	11	1	3	9		13	1	9	3	1	3		
Small business/inventors																
Software developers			1	2					1		1	1				
Standards development organizations (SDOs)	1			2			1		5		2	1				
Testing laboratories																
Universities	1	1	7	2		1	2		2		4			1		

Exhibit 3.10: MN Correlation Matrix for Measurement Barriers and Measurement Solutions in Defense and Homeland Security

	Measurement Solutions																								
	Infrastructure								Products													Services			
Measurement Solution Barriers	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Acceptability/Compatibility			1				3	1	1			2	2					1	1	1					1
Accessibility			1						1										1						
Accuracy		1	6	2	1	2	3	2	4	2	7	5	3	3			1	2	2	1	1		1		1
Data, Data Collection/and or Retrieval		2	2	2	2	1	3		3	2	5	2	2		2			2	1	3	1				1
Destructive				1		1						1													
Expense		2						1	2	1	1				1				1						
Lack of Fundamental Knowledge			2	2		3	1	1	1	1	4	3	1	1	2		1			1					
Multiple Solutions Exist																									
Not Standardized			2	1	3	1	7	1	3	1	4	4	5	2	1			3		6	1		1		2
Production Readiness					1							1							1						
Reliability			3	2	1		3		1	1		6	4	3			1	1	2				1		1
Resolution			1	1			1		1	2	1		1		1					1					
Small Market Demand							1						1					1							
Speed		1	1							1	1	2			1										
System-Level Problem																									
Workforce																									

Exhibit 3.11: MN Correlation Matrix for Measurement Providers and Measurement Solutions in Defense and Homeland Security

	Measurement Solutions																									
	Infrastructure								Products														Services			
Measurement Solution Providers	**Coordination/ facilitation**	**Data Collection/ Retrieval**	**Development for Measurement Technology**	**Fundamental Scientific Knowledge**	**Protocols**	**Research for Measurement Science**	**Standards**	**User Facility**	**Calibration Method**	**Computation Method**	**Measurement Instrument**	**Measurement Method**	**Metrics/ Benchmarks**	**Raw Properties Data**	**Reference Data**	**Software**	**Stability Tests**	**Standard/CRM**	**Test Methods - Production Scale**	**Test Methods - Consumer Products**	**Validated Data**	**Calibration Services**	**Expert Consultation**	**International Recognition**	**3rd Party Verification**
Calibration laboratories																										
Commercial calibration service providers									1		1				1											
Component suppliers						1		1			1															
Contractor R&D labs-for-hire							1				1	1						1			1					
Engineering management/consulting firms/A&E firms					1													1		1						
Government laboratories and agencies		1	4	4	4	2	4		2	3	4	9	3	3	4		1	3	1	4	1		1		2	
Independent testing/certification laboratories																										
Industrial R&D laboratories			2	1		1	1			1		3	2	1	1										1	
Industry consortium/partnership							2		1		1		2					1		1						
Instrument suppliers			3	2	1	1	4	1	4	2	3	2	2	2			1	1	3	2					1	
Material suppliers						1		1			1															
National Measurement Institute		2	6	3	4	2	7	1	5	3	7	9	6	2	4		1	4	3	6	1		1		2	
Small business/inventors																										
Software developers				2					1	1			1					1								
Standards development organizations (SDOs)			1		1		3					2	3							3						
Testing laboratories																										
Universities		1	3			1	2	1	2	1	3	4	1	1	1				1							

Exhibit 3.12: MN Correlation Matrix for Stage of Technological Innovation and Measurement Barriers in Defense and Homeland Security

Stage of Technological Innovation	Measurement Solution Barriers															
	Acceptability/Compatibility	Accessibility	Accuracy	Data, Data Collection and/or Retrieval	Destructive	Expense	Lack of fundamental knowledge	Multiple Solutions Exist	Not Standardized	Production Readiness	Reliability	Resolution	Small Market Demand	Speed	System-Level Problem	Workforce
Applied Research	2	1	15	10	1	1	10		12	1	10	4		2		
Production	1		1			1			1							
Market	2		1	1					3				1			
End-use			1	1		1			1		1			1		

Exhibit 3.13: MN Correlation Matrix for Stage of Technological Innovation and Measurement Solutions in Defense and Homeland Security

	Measurement Solutions																								
	Infrastructure								Products													Services			
Stage of Technological Innovation	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Applied Research		1	6	4	2	3	6	1	5	3	8	10	5	3	3		1	2	2	3	1				1
Production					1			1	1									1	1	1					
Market			1		1		2						1					1		2					1
End-use		1								1		1	1		1								1		

Exhibit 3.14: MN Correlation Matrix for Solution Providers and Stage of Technological Innovation in Defense and Homeland Security

Measurement Solution Providers	Stage of Technological Innovation			
	Applied Research	Production	Market	End-use
Calibration laboratories				
Commercial calibration service providers	1			
Component suppliers	1			
Contractor R&D labs-for-hire	2			
Engineering management/consulting firms/A&E firms		1		
Government laboratories and agencies	18	1	2	2
Independent testing/certification laboratories				
Industrial R&D laboratories	6			
Industry consortium/partnership	2		1	
Instrument suppliers	9	1	2	
Material suppliers	1			
National Measurement Institute	23	2	3	2
Small business/inventors				
Software developers	2			
Standards development organizations (SDOs)	5			
Testing laboratories				
Universities	8			

Exhibit 3.15: MN Correlation Matrix for Stage of Technological Innovation and TI as Measurement Technology in Defense and Homeland Security

Stage of Technological Innovation	TI as Measurement Technology
Applied Research	17
Production	
Market	1
End-use	1

Exhibit 3.16: MN Correlation Matrix for TI as Measurement Technology and Measurement Barriers in Defense and Homeland Security

Innovation Equivalency	Measurement Solution Barriers															
	Acceptability/Compatibility	Accessibility	Accuracy	Data, Data Collection and/or Retrieval	Destructive	Expense	Lack of fundamental knowledge	Multiple Solutions Exist	Not Standardized	Production Readiness	Reliability	Resolution	Small Market Demand	Speed	System-Level Problem	Workforce
Technology Innovation = Measurement Innovation		1	11	9		2	6		10	1	5	4		2		

Exhibit 3.17: MN Correlation Matrix for Solution Providers and TI as Measurement Technology in Defense and Homeland Security

Measurement Solution Providers	Technology Innovation = Measurement Innovation
Calibration laboratories	
Commercial calibration service providers	1
Component suppliers	1
Contractor R&D labs-for-hire	1
Engineering management/consulting firms/A&E firms	
Government laboratories and agencies	14
Independent testing/certification laboratories	
Industrial R&D laboratories	3
Industry consortium/partnership	1
Instrument suppliers	8
Material suppliers	1
National Measurement Institute	16
Small business/inventors	
Software developers	1
Standards development organizations (SDOs)	3
Testing laboratories	
Universities	4

Exhibit 3.18: MN Correlation Matrix for TI as Measurement Technology and Measurement Solutions in Defense and Homeland Security

	Measurement Solutions																								
	Infrastructure								Products													Services			
Innovation Equivalency	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Technology Innovation = Measurement Innovation		2	4	2	3	2	5	1	4	3	6	3	2	3	3		1	1	2	4	1				1

Exhibit 3.19: MN Correlation Matrix for Regulation as Driver/Barrier and Measurement Solutions in Defense and Homeland Security

	Measurement Solutions																							
	Infrastructure								Products													Services			
Regulatory Issues	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Regulation is a Driver							2					2		1											1
Regulation is a Barrier		1								1					1										

Exhibit 3.20: MN Correlation Matrix for Solution Providers and Regulation as Driver/Barrier in Defense and Homeland Security

Measurement Solution Providers	Regulation is a Driver	Regulation is a Barrier
Calibration laboratories		
Commercial calibration service providers		
Component suppliers		
Contractor R&D labs-for-hire	1	
Engineering management/consulting firms/A&E firms		
Government laboratories and agencies	2	1
Independent testing/certification laboratories		
Industrial R&D laboratories	1	
Industry consortium/partnership		
Instrument suppliers		
Material suppliers		
National Measurement Institute	3	1
Small business/inventors		
Software developers		
Standards development organizations (SDOs)	1	
Testing laboratories		
Universities	1	

U.S. Measurement System

Measurement Need (MN) Data Book

Chapter 4. Electronics for Non-Semiconductor and Information Technology (IT) Hardware

Prepared by
Energetics Incorporated
for the
National Institute of Standards and Technology

April 2006

Reference List of MN Distribution Charts and MN Correlation Matrices

Exhibit 4.1: MN Distribution of Measurement Barriers in Electronics for Non-Semiconductor and IT Hardware

Acceptibility	Accessibility	Accuracy	Data, Data Collection & Retrieval	Destructive	Expense	Lack of Fundamental Knowledge	Multiple Solutions	Not Standardized	Production Readiness	Reliability	Resolution	Small market demand	Speed	Systems-level	Workforce	Total
6	4	52	16	1	6	17	3	22	8	17	13	0	9	1	0	175

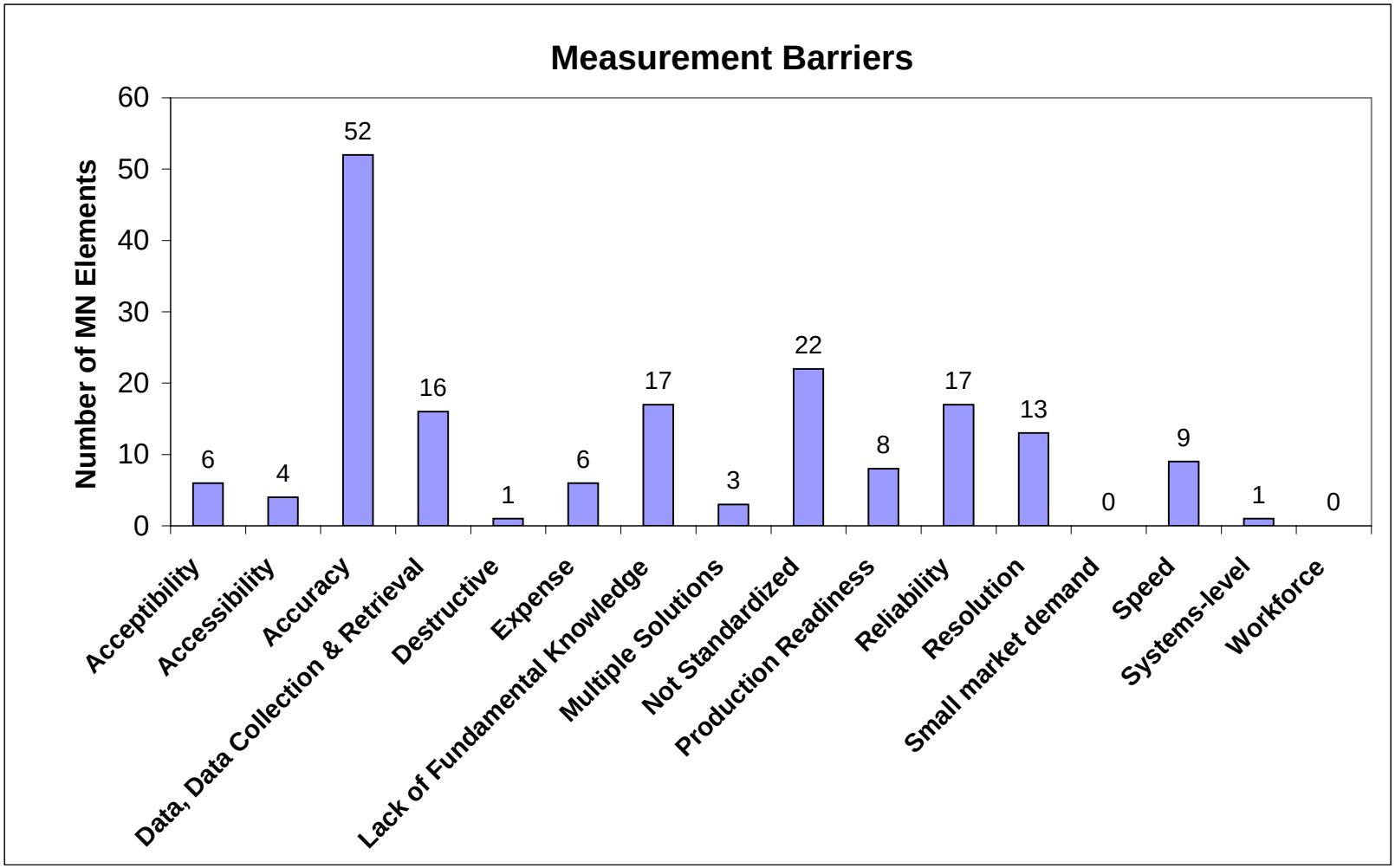

Exhibit 4.2: MN Distribution of Measurement Solution Providers in Electronics for Non-Semiconductor and IT Hardware

Calibration Laboratories	Commercial Calibration Service Providers	Component Suppliers	Contractor R&D Labs-for-Hire	Engineering Management/Consulting Firms/A&E Firms	Government Laboratories and Agencies	Independent Testing/Certification Laboratories	Industrial R&D Laboratories	Industry Consortium/ Partnership	Instrument Suppliers	Material Suppliers	National Measurement Institute	Small Business/Inventors	Software Developers	Standards Development Organizations (SDO)	Testing Laboratories	Universities	Total
1	0	13	2	0	69	2	27	20	31	2	50	0	3	9	0	40	269

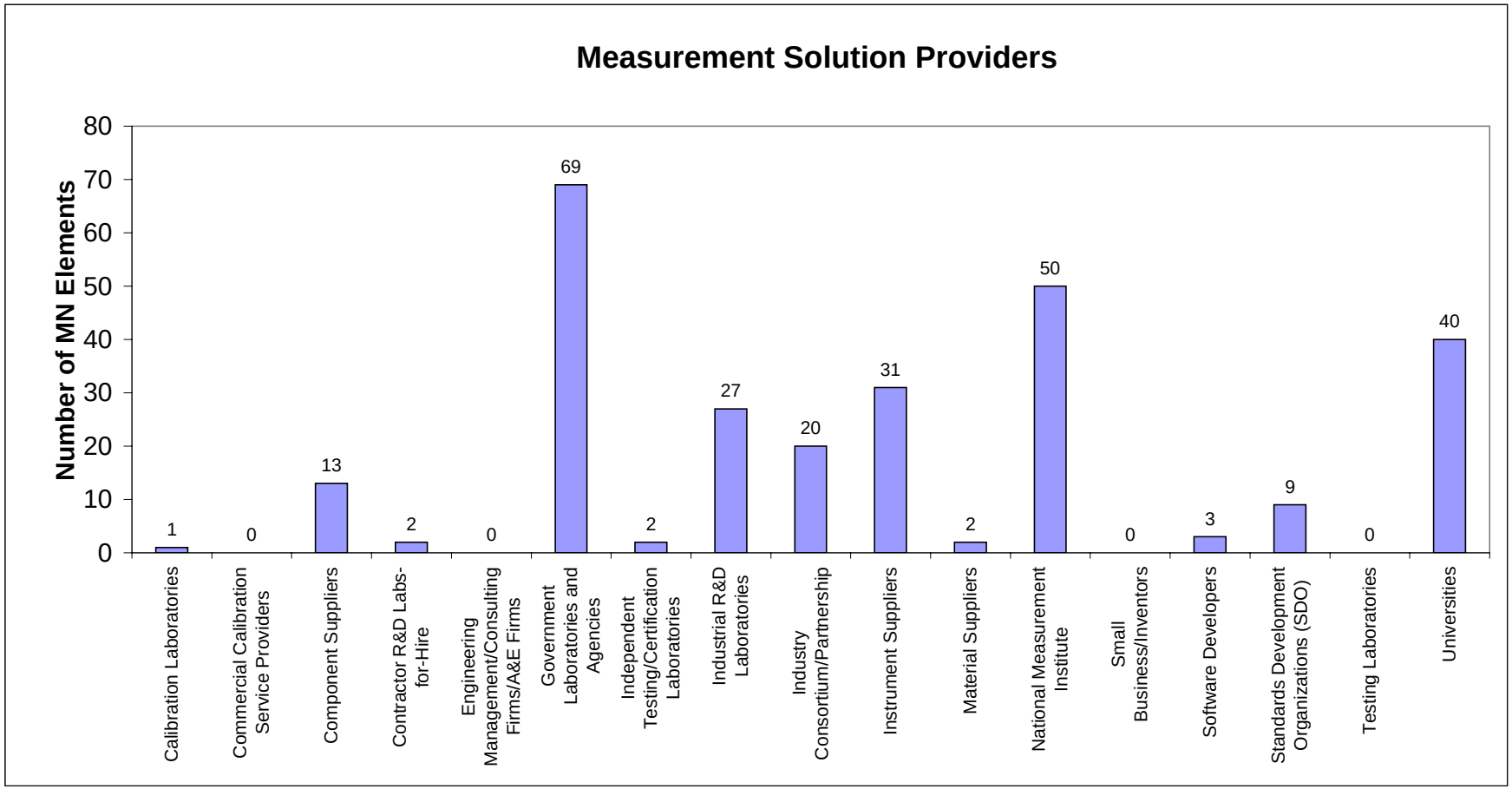

Exhibit 4.3: MN Distribution of Measurement Solutions in Electronics for Non-Semiconductor and IT Hardware

Infrastructure								Products												Services				
Coordination/Facilitation	Data Collection/Retrieval	Development - Measurement Technology	Fund-amental Knowledge	Protocols	Research - Measure-ment Science	Standards	User Facility	Calibration	Computational Methods	Measure-ment Instrument	Measure-ment Method	Metrics/Benchmarks	Raw Data	Reference Data	Software	Stability Tests	Standard/certified reference material	Test methods for production-scale measurements	Test methods or test data for consumer products	Validated (hardened) properties data	Calibration	Expert consultation	Intl Recognition	Third Party Verification	Total
3	0	44	6	9	15	33	3	7	10	10	16	7	2	5	1	0	6	10	3	2	0	0	1	3	196

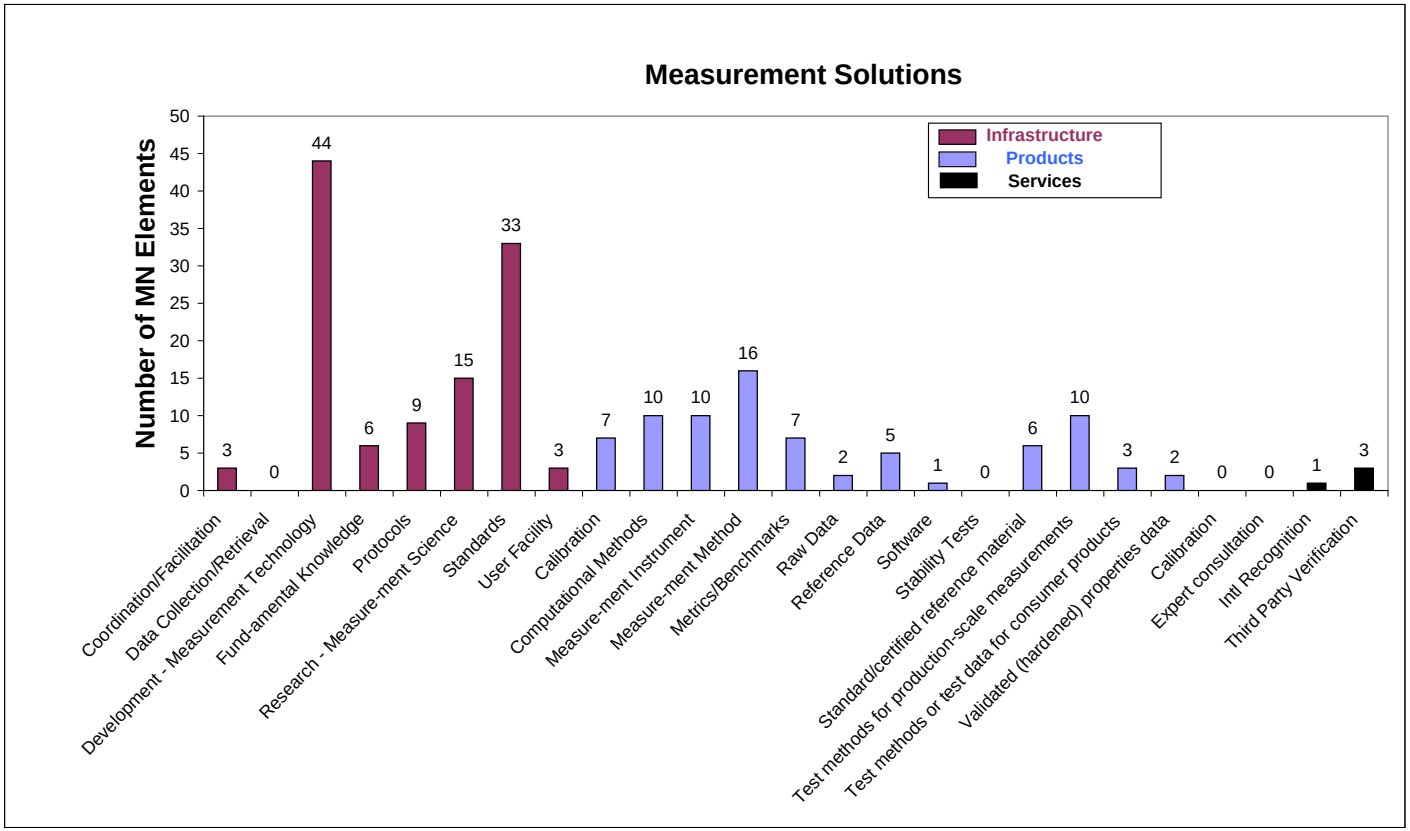

Exhibit 4.4: MN Distribution of Measurands in Electronics for Non-Semiconductor and IT Hardware

Classical				Functional									Performance			Structural				
Biological	Chemical	Physical	Physiological	Acoustical	Electronic/ Electrical	Magnetic	Optical	Photonic	Radio frequency	Thermal- Thermochemical	Thermal- Thermodynamic	Thermal- Thermophysical	Computational Performance	Software Performance	System Performance	Kinetic	Mechanical	Molecular	Spatial	Total
0	5	27	1	0	20	9	5	4	4	0	2	2	2	0	7	0	3	2	1	94

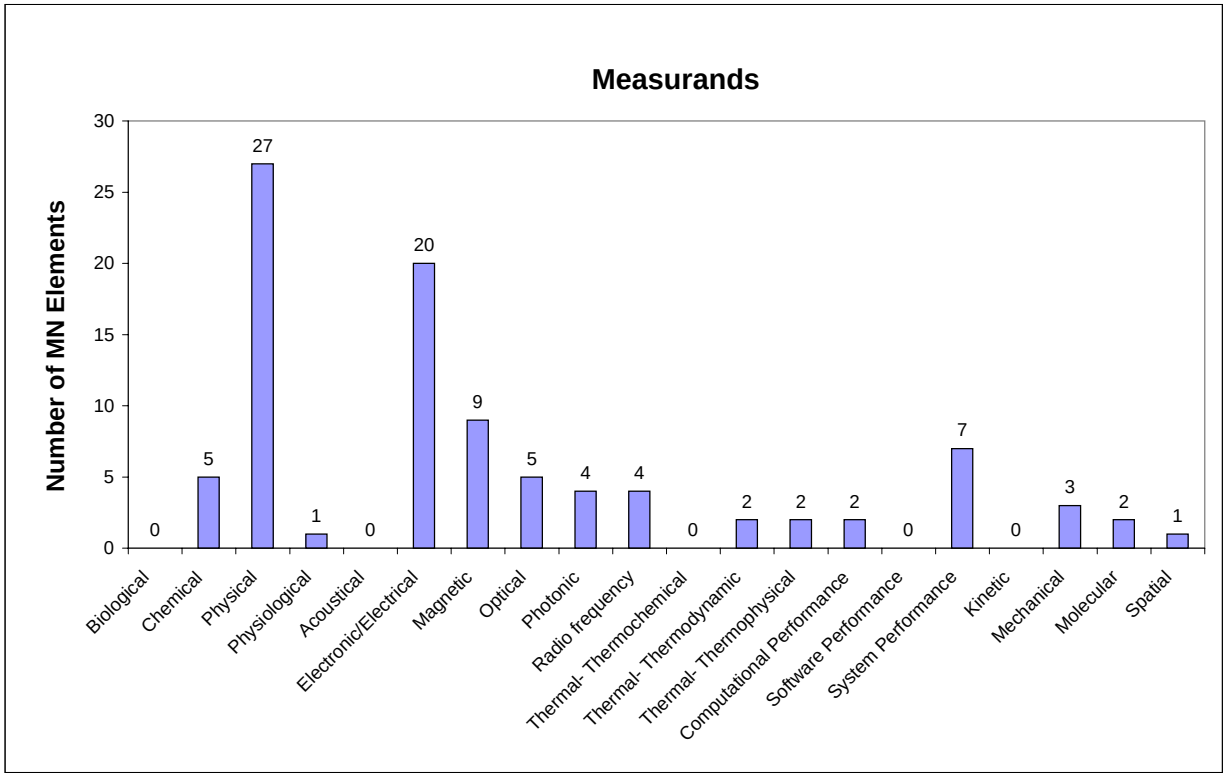

Exhibit 4.5: MN Distribution of Current Public/Private R&D Efforts in Electronics for Non-Semiconductor and IT Hardware

Only Private Efforts Exist	Only Public Efforts Exist	Both Public and Private Efforts Exist	No Efforts Exist
24	5	35	30

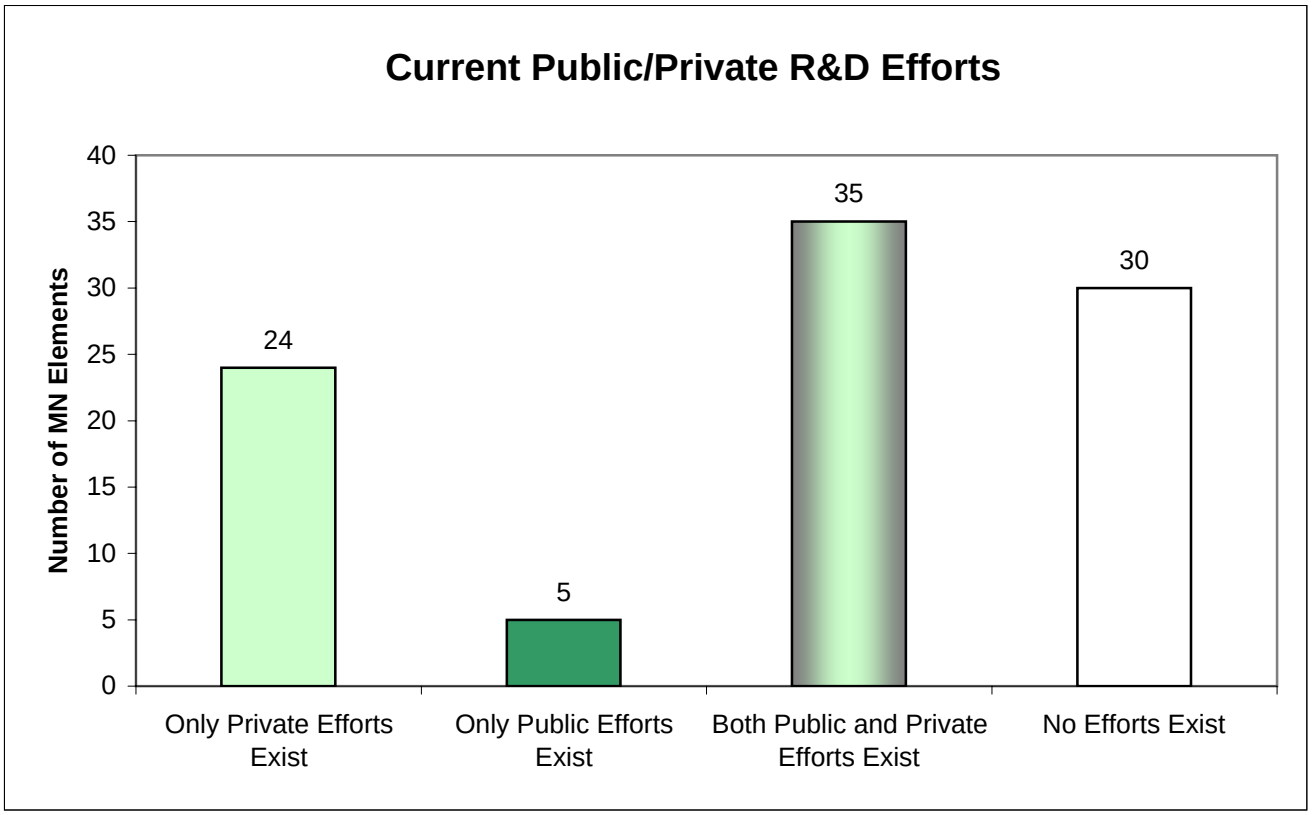

Exhibit 4.6: MN Distribution of TI as Measurement Technology in Electronics for Non-Semiconductor and IT Hardware

Technology Innovation is a Measurement Innovation	Technology Innovation is not a Measurement Innovation
21	73

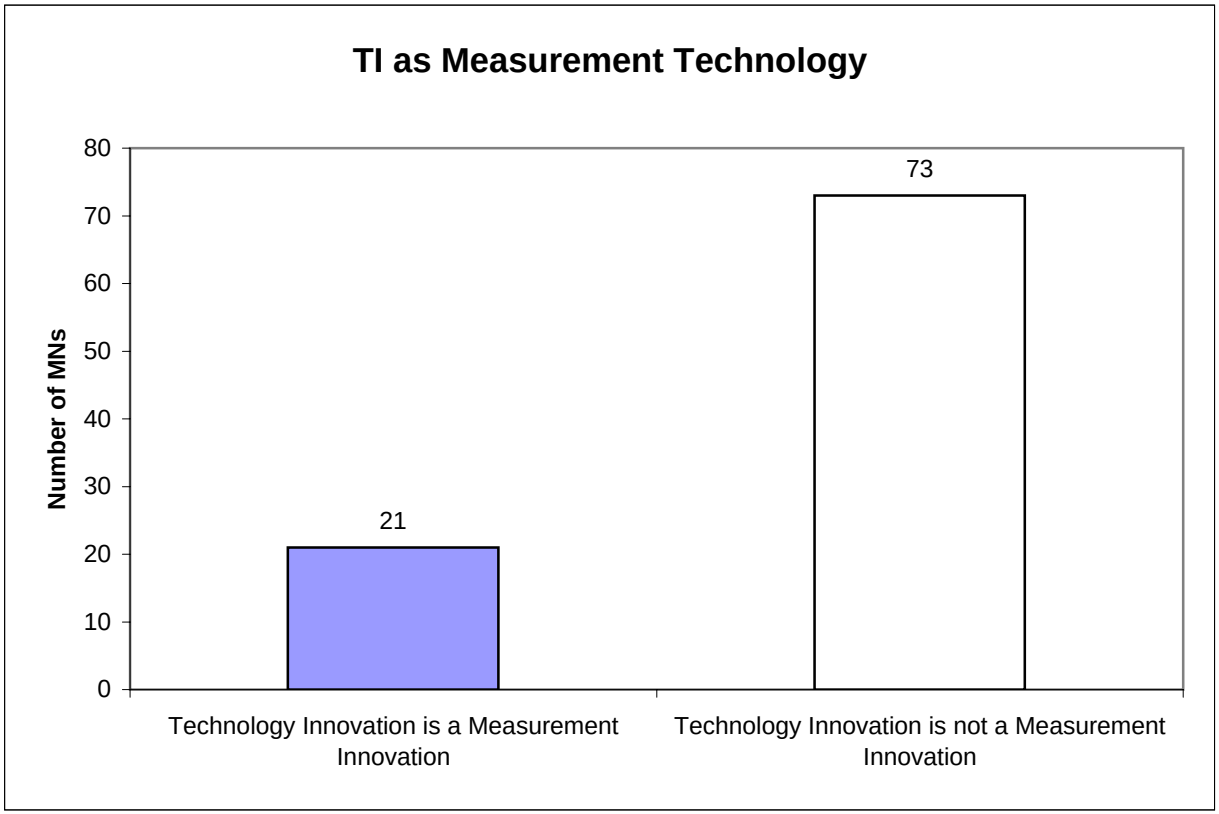

Exhibit 4.7: MN Distribution by Stage of Technological Innovation in Electronics for Non-Semiconductor and IT Hardware

Applied Research	Production	Market	End-use	Total
64	14	12	4	94

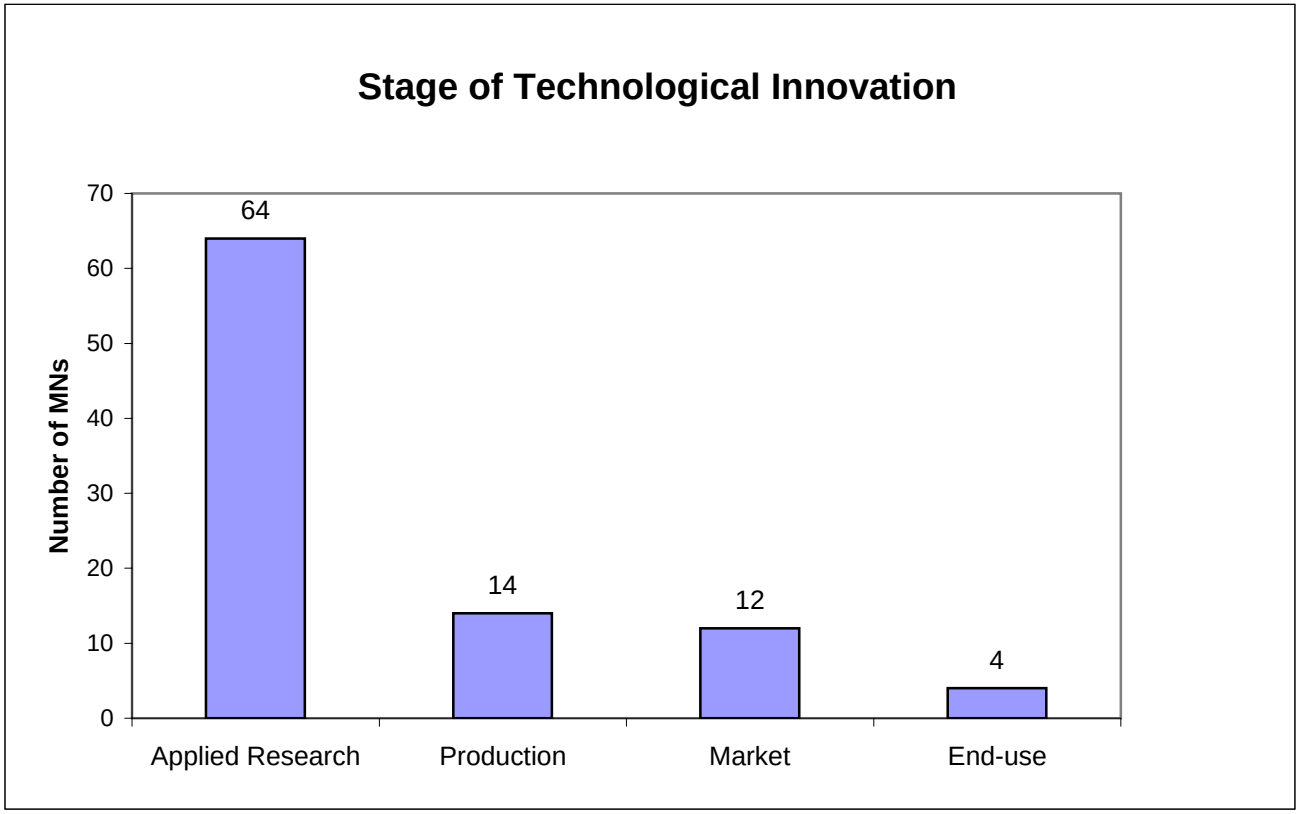

Exhibit 4.8: MN Distribution of Regulation as Driver/Barrier in Electronics for Non-Semiconductor and IT Hardware

MN Driver	MN Barrier	No Impact
3	1	90

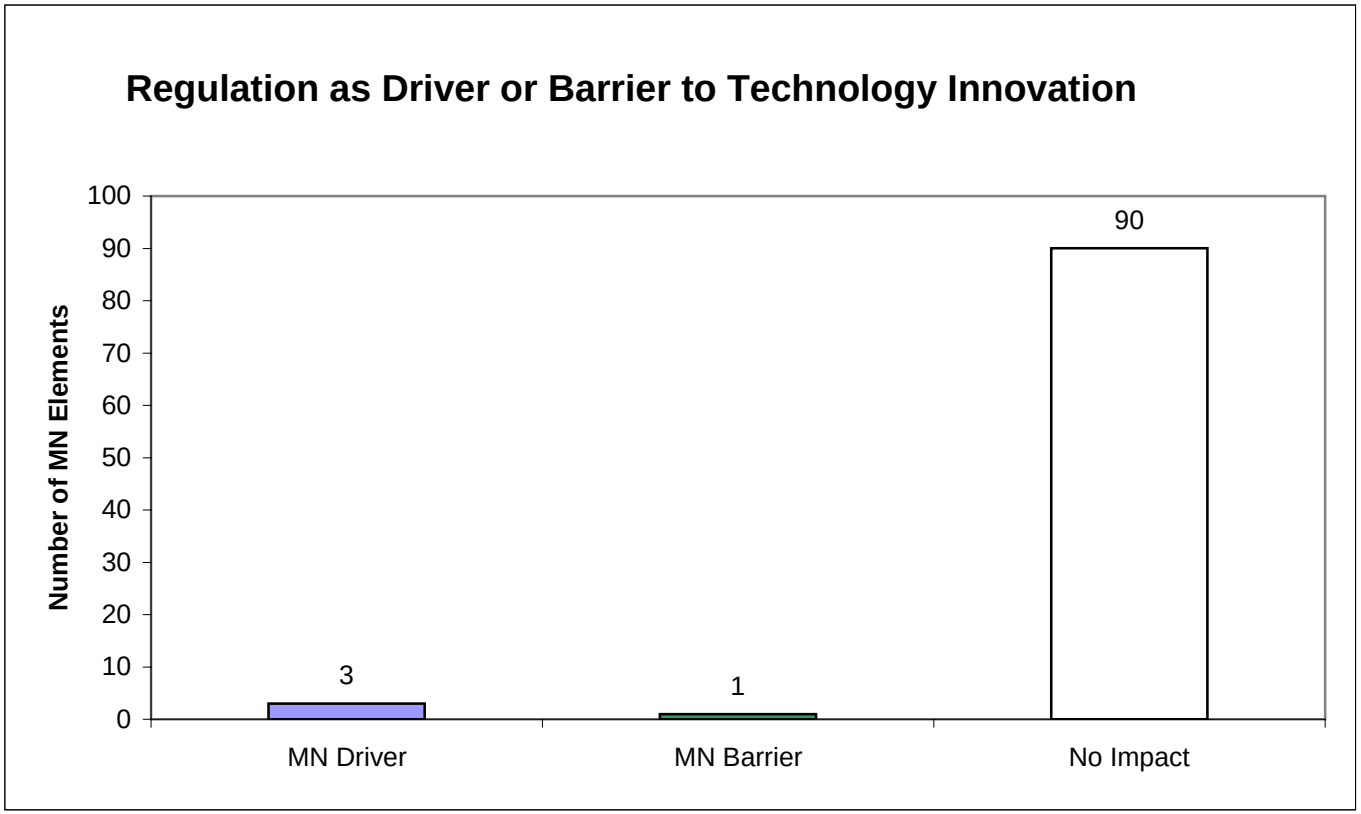

Exhibit 4.9: MN Correlation Matrix for Solution Providers and Measurement Barriers in Electronics for Non-Semiconductor and IT Hardware

Solution Providers	Measurement Solution Barriers															
	Acceptability/Compatibility	Accessibility	Accuracy	Data, Data Collection and/or Retrieval	Destructive	Expense	Lack of fundamental knowledge	Multiple Solutions Exist	Not Standardized	Production Readiness	Reliability	Resolution	Small Market Demand	Speed	System-Level Problem	Workforce
Calibration laboratories			1			1										
Commercial calibration service providers																
Component suppliers			8	2		2	1		6		4	3				
Contractor R&D labs-for-hire			2	1			1				1					
Engineering management/consulting firms/A&E firms																
Government laboratories and agencies	3	2	39	9		5	15	3	12	5	11	11		6	1	
Independent testing/certification laboratories	1			1					2		1					
Industrial R&D laboratories	1		10	2		1	9		9	1	3	3			1	
Industry consortium/partnership	1	3	12	5	1	3	2		4	1	6	4		7		
Instrument suppliers	3	2	15	5		1	3		6	6	6	5		2		
Material suppliers			1				1		1	1						
National Measurement Institute	5	4	29	9	1	3	5	3	10	6	8	5		6	1	
Small business/inventors																
Software developers			2		1						1			1		
Standards development organizations (SDOs)	2		3	3				1	3	1	1	1		1		
Testing laboratories																
Universities	1	1	25	10		2	12	2	8	3	7	7		3		

Exhibit 4.10: MN Correlation Matrix for Measurement Barriers and Measurement Solutions in Electronics for Non-Semiconductor and IT Hardware

	Measurement Solutions																								
	Infrastructure								Products													Services			
Measurement Solution Barriers	**Coordination/ facilitation**	**Data Collection/ Retrieval**	**Development for Measurement Technology**	**Fundamental Scientific Knowledge**	**Protocols**	**Research for Measurement Science**	**Standards**	**User Facility**	**Calibration Method**	**Computation Method**	**Measurement Instrument**	**Measurement Method**	**Metrics/ Benchmarks**	**Raw Properties Data**	**Reference Data**	**Software**	**Stability Tests**	**Standard/CRM**	**Test Methods - Production Scale**	**Test Methods - Consumer Products**	**Validated Data**	**Calibration Services**	**Expert Consultation**	**International Recognition**	**3rd Party Verification**
Acceptability/Compatibility	1		1	1	1	1	5					1	1					1	2	1				1	1
Accessibility	1				1		3		1		1	2													1
Accuracy	1		29	3	4	9	17	3	7	6	6	8	4		1			5	3	2					1
Data, Data Collection/and or Retrieval	1		5		2	2	5	1	3	4	2	5	1	2	1			1	3	3	1				3
Destructive			1		1					1															
Expense			3			2	2		1		4	2	1					2							
Lack of Fundamental Knowledge	1		8	6	1	8	3	1	1	2	3	3	2		2										
Multiple Solutions Exist			1					1	1		1	1	1	1											
Not Standardized	2		3		4	1	14	1	2	1	2	5	2	1	1	1		1	4	1	1			1	2
Production Readiness			6		1	1					1	1							2						
Reliability	1		6		2	2	4		3	5	3	3	2	1	1	1		2	4	1	2				1
Resolution			13	1		3	4	1		1	1	1		1					3						
Small Market Demand																									
Speed			8		2	2	3			1	3	3						2	1						
System-Level Problem							1																		
Workforce																									

Exhibit 4.11: MN Correlation Matrix for Measurement Providers and Measurement Solutions in Electronics for Non-Semiconductor and IT Hardware

	Measurement Solutions																									
	Infrastructure								Products														Services			
Measurement Solution Providers	**Coordination/ facilitation**	**Data Collection/ Retrieval**	**Development for Measurement Technology**	**Fundamental Scientific Knowledge**	**Protocols**	**Research for Measurement Science**	**Standards**	**User Facility**	**Calibration Method**	**Computation Method**	**Measurement Instrument**	**Measurement Method**	**Metrics/ Benchmarks**	**Raw Properties Data**	**Reference Data**	**Software**	**Stability Tests**	**Standard/CRM**	**Test Methods - Production Scale**	**Test Methods - Consumer Products**	**Validated Data**	**Calibration Services**	**Expert Consultation**	**International Recognition**	**3rd Party Verification**
Calibration laboratories			1			1												1								
Commercial calibration service providers																										
Component suppliers			5			1	8	1	1		2	2	1					1	1							1
Contractor R&D labs-for-hire	1								1	1	1		1							1						
Engineering management/consulting firms/A&E firms																										
Government laboratories and agencies	2		36	5	3	11	22	2	3	6	7	10	7	2	4	1		4	5	3	2					1
Independent testing/certification laboratories							1											1	2						1	1
Industrial R&D laboratories	1		12	2	1	8	8			4	1	5	3		4	1		1	2	1	1					
Industry consortium/partnership	1		11	1	4	3	7		3	3	5	3						2	4		1					2
Instrument suppliers	1		17	3	5	3	12	1	2	3	3	4	1						4	1						1
Material suppliers						1		1			1								1							
National Measurement Institute	1		20	1	6	8	21	2	5	4	6	11	3	2	2			5	3	1					1	2
Small business/inventors																										
Software developers			1		1					2		1	1						1							
Standards development organizations (SDOs)			4		2		4					1	1		1			1	3						1	
Testing laboratories																										
Universities	2		22	5	1	8	6	2	3	7	4	7	3	2	3	1		2	4	2	2					1

Exhibit 4.12: MN Correlation Matrix for Stage of Technological Innovation and Measurement Barriers in Electronics for Non-Semiconductor and IT Hardware

Stage of Technological Innovation	Measurement Solution Barriers															
	Acceptability/Compatibility	Accessibility	Accuracy	Data, Data Collection and/or Retrieval	Destructive	Expense	Lack of fundamental knowledge	Multiple Solutions Exist	Not Standardized	Production Readiness	Reliability	Resolution	Small Market Demand	Speed	System-Level Problem	Workforce
Applied Research	2	3	38	10	1	5	14	1	12	5	13	8		8	1	
Production		1	7	2			1		5	3	1	2				
Market	4		5	3			1	2	4		1	3		1		
End-use			2	1		1	1		1		2					

Exhibit 4.13: MN Correlation Matrix for Stage of Technological Innovation and Measurement Solutions in Electronics for Non-Semiconductor and IT Hardware

	Measurement Solutions																								
	Infrastructure								Products													Services			
Stage of Technological Innovation	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Applied Research	3		32	4	5	12	19	3	5	9	9	13	6	1	4	1		3	6	2	2				1
Production			5	1	1		6		1					1			1								1
Market			4	1	2	1	6			1	1	1	1	1				1	4	1				1	1
End-use			3		1	2	2		1			1						1							

Exhibit 4.14: MN Correlation Matrix for Solution Providers and Stage of Technological Innovation in Electronics for Non-Semiconductor and IT Hardware

Measurement Solution Providers	Stage of Technological Innovation			
	Applied Research	Production	Market	End-use
Calibration laboratories				1
Commercial calibration service providers				
Component suppliers	5	5	2	1
Contractor R&D labs-for-hire	2			
Engineering management/consulting firms/A&E firms				
Government laboratories and agencies	48	12	7	2
Independent testing/certification laboratories	1		1	
Industrial R&D laboratories	22	3	1	1
Industry consortium/partnership	14	2	4	
Instrument suppliers	20	5	5	1
Material suppliers	2			
National Measurement Institute	36	5	6	3
Small business/inventors				
Software developers	2		1	
Standards development organizations (SDOs)		3	5	1
Testing laboratories				
Universities	32	5	3	

Exhibit 4.15: MN Correlation Matrix for Stage of Technological Innovation and TI as Measurement Technology in Electronics for Non-Semiconductor and IT Hardware

Stage of Technological Innovation	TI as Measurement Technology
Applied Research	17
Production	1
Market	2
End-use	1

Exhibit 4.16: MN Correlation Matrix for TI as Measurement Technology and Measurement Barriers in Electronics for Non-Semiconductor and IT Hardware

	Measurement Solution Barriers															
Innovation Equivalency	**Acceptability/Compatibility**	**Accessibility**	**Accuracy**	**Data, Data Collection and/or Retrieval**	**Destructive**	**Expense**	**Lack of fundamental knowledge**	**Multiple Solutions Exist**	**Not Standardized**	**Production Readiness**	**Reliability**	**Resolution**	**Small Market Demand**	**Speed**	**System-Level Problem**	**Workforce**
Technology Innovation = Measurement Innovation	1		11	4		3	5	1	5	2	5	1		1		

Exhibit 4.17: MN Correlation Matrix for Solution Providers and TI as Measurement Technology in Electronics for Non-Semiconductor and IT Hardware

Measurement Solution Providers	Technology Innovation = Measurement Innovation
Calibration laboratories	1
Commercial calibration service providers	
Component suppliers	2
Contractor R&D labs-for-hire	1
Engineering management/consulting firms/A&E firms	
Government laboratories and agencies	16
Independent testing/certification laboratories	
Industrial R&D laboratories	8
Industry consortium/partnership	2
Instrument suppliers	6
Material suppliers	1
National Measurement Institute	13
Small business/inventors	
Software developers	1
Standards development organizations (SDOs)	1
Testing laboratories	
Universities	7

Exhibit 4.18: MN Correlation Matrix for TI as Measurement Technology and Measurement Solutions in Electronics for Non-Semiconductor and IT Hardware

	Measurement Solutions																								
	Infrastructure								Products														Services			
Innovation Equivalency	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Technology Innovation = Measurement Innovation			4		2	4	7	1	2	1	6	7	3	1	2	1		1	3		1				

Exhibit 4.19: MN Correlation Matrix for Regulation as Driver/Barrier and Measurement Solutions in Electronics for Non-Semiconductor and IT Hardware

	Measurement Solutions																							
	Infrastructure								Products													Services			
Regulatory Issues	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Regulation is a Driver	1		1		1	1	1		1			1						1							1
Regulation is a Barrier																		1	1					1	

Exhibit 4.20: MN Correlation Matrix for Solution Providers and Regulation as Driver/Barrier in Electronics for Non-Semiconductor and IT Hardware

Measurement Solution Providers	Regulation is a Driver	Regulation is a Barrier
Calibration laboratories	1	
Commercial calibration service providers		
Component suppliers		
Contractor R&D labs-for-hire		
Engineering management/consulting firms/A&E firms		
Government laboratories and agencies	1	
Independent testing/certification laboratories		1
Industrial R&D laboratories		
Industry consortium/partnership	2	
Instrument suppliers	1	
Material suppliers		
National Measurement Institute	3	1
Small business/inventors		
Software developers		
Standards development organizations (SDOs)		1
Testing laboratories		
Universities	1	

U.S. Measurement System

Measurement Need (MN) Data Book

Chapter 5. Electronics Semiconductor

Prepared by
Energetics Incorporated
for the
National Institute of Standards and Technology

April 2006

Reference List of MN Distribution Charts and MN Correlation Matrices

Exhibit 5.1: MN Distribution of Measurement Barriers in Electronics Semiconductor

Acceptibility	Accessibility	Accuracy	Data, Data Collection & Retrieval	Destructive	Expense	Lack of Fundamental Knowledge	Multiple Solutions	Not Standardized	Production Readiness	Reliability	Resolution	Small market demand	Speed	Systems-level	Workforce	Total
2	1	38	8	1	6	13	0	3	2	12	22	0	13	0	0	121

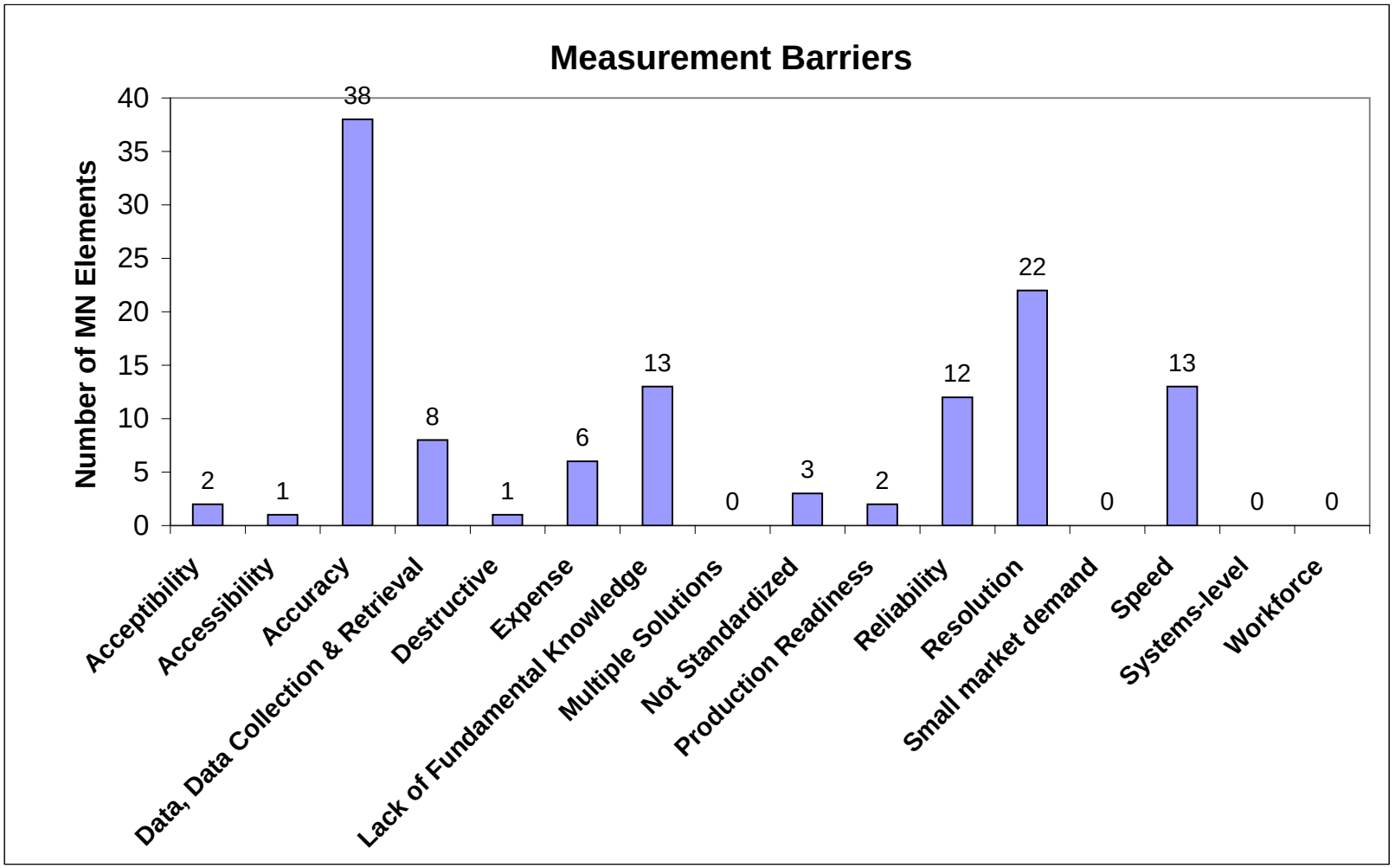

Exhibit 5.2: MN Distribution of Measurement Solution Providers in Electronics Semiconductor

Calibration Laboratories	Commercial Calibration Service Providers	Component Suppliers	Contractor R&D Labs-for-Hire	Engineering Management/Consulting Firms/A&E Firms	Government Laboratories and Agencies	Independent Testing/Certification Laboratories	Industrial R&D Laboratories	Industry Consortium/ Partnership	Instrument Suppliers	Material Suppliers	National Measurement Institute	Small Business/Inventors	Software Developers	Standards Development Organizations (SDO)	Testing Laboratories	Universities	Total
1	0	0	1	0	34	0	16	22	10	2	38	0	2	1	0	19	146

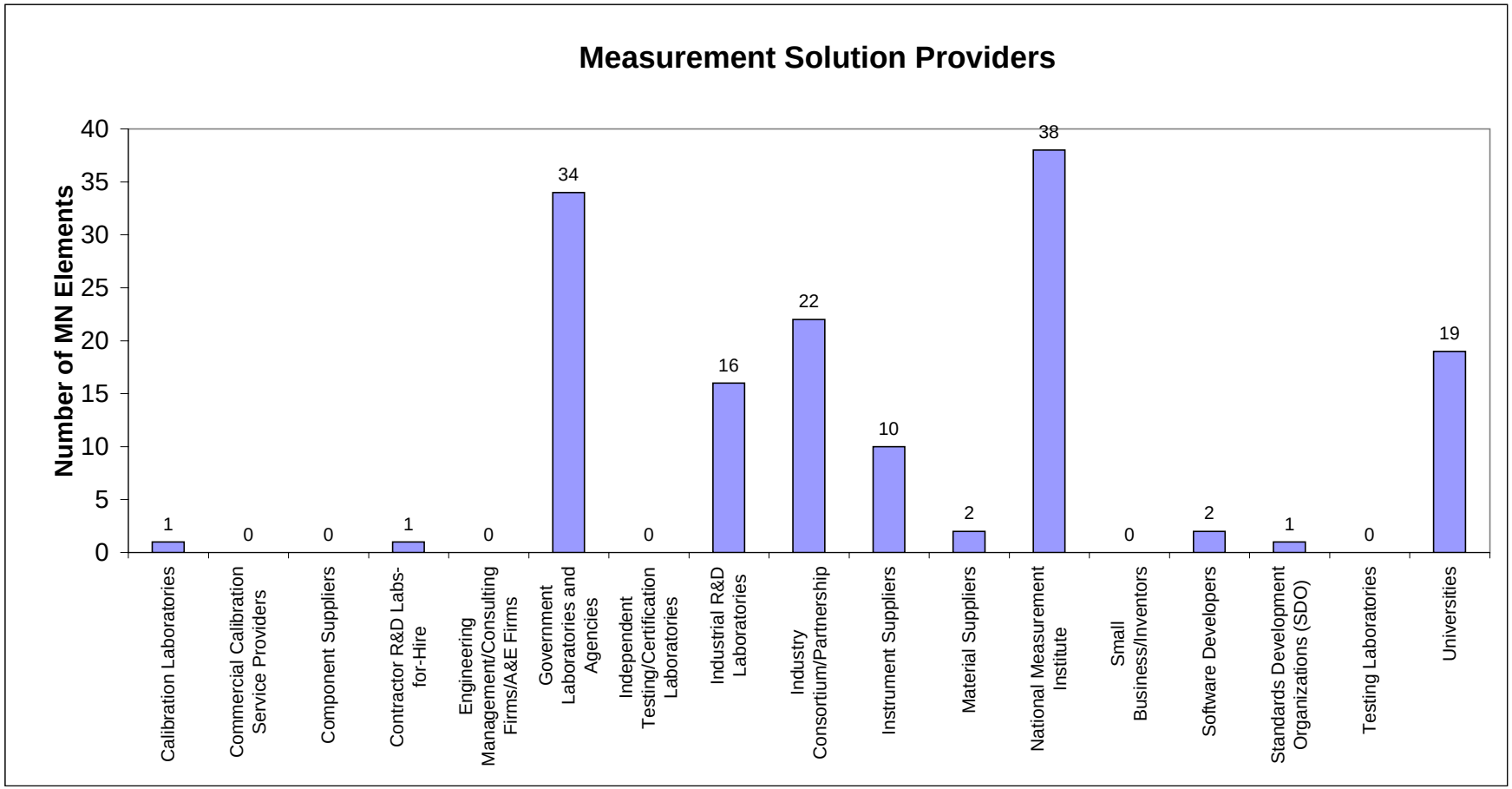

Exhibit 5.3: MN Distribution of Measurement Solutions in Electronics Semiconductor

Infrastructure								Products												Services				
Coordination/Facilitation	Data Collection/Retrieval	Development - Measurement Technology	Fund-amental Knowledge	Protocols	Research - Measure-ment Science	Standards	User Facility	Calibration	Computational Methods	Measure-ment Instrument	Measure-ment Method	Metrics/Benchmarks	Raw Data	Reference Data	Software	Stability Tests	Standard/certified reference material	Test methods for production-scale measurements	Test methods or test data for consumer products	Validated (hardened) properties data	Calibration	Expert consultation	Intl Recognition	Third Party Verification	Total
0	0	31	2	2	12	8	5	7	10	16	13	1	3	2	1	0	7	6	0	1	1	1	0	1	130

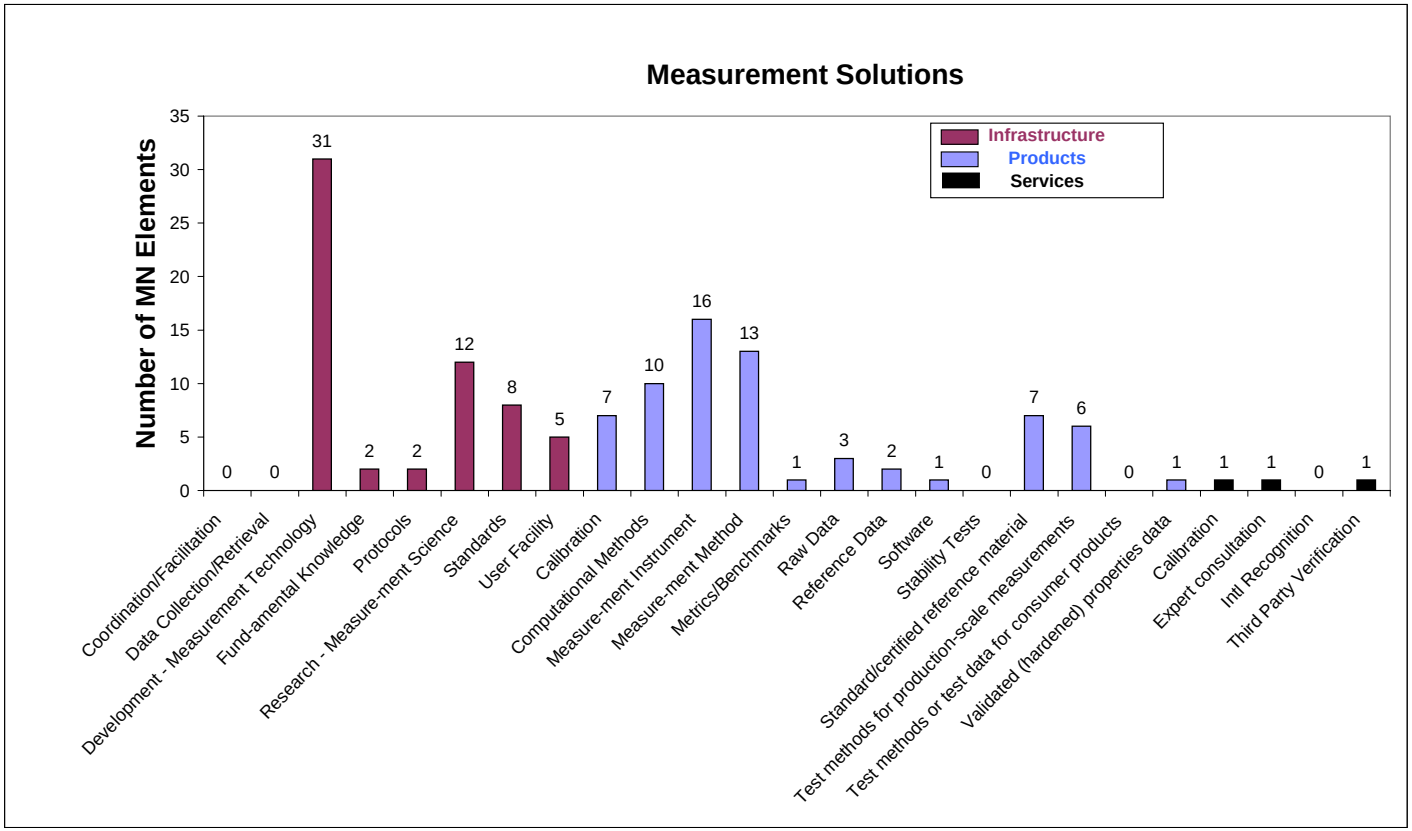

Exhibit 5.4: MN Distribution of Measurands in Electronics Semiconductor

Classical				Functional									Performance			Structural				
Biological	Chemical	Physical	Physiological	Acoustical	Electronic/ Electrical	Magnetic	Optical	Photonic	Radio frequency	Thermal- Thermochemical	Thermal- Thermodynamic	Thermal- Thermophysical	Computational Performance	Software Performance	System Performance	Kinetic	Mechanical	Molecular	Spatial	Total
0	3	19	0	0	13	3	6	1	1	0	0	2	0	0	0	0	2	2	0	52

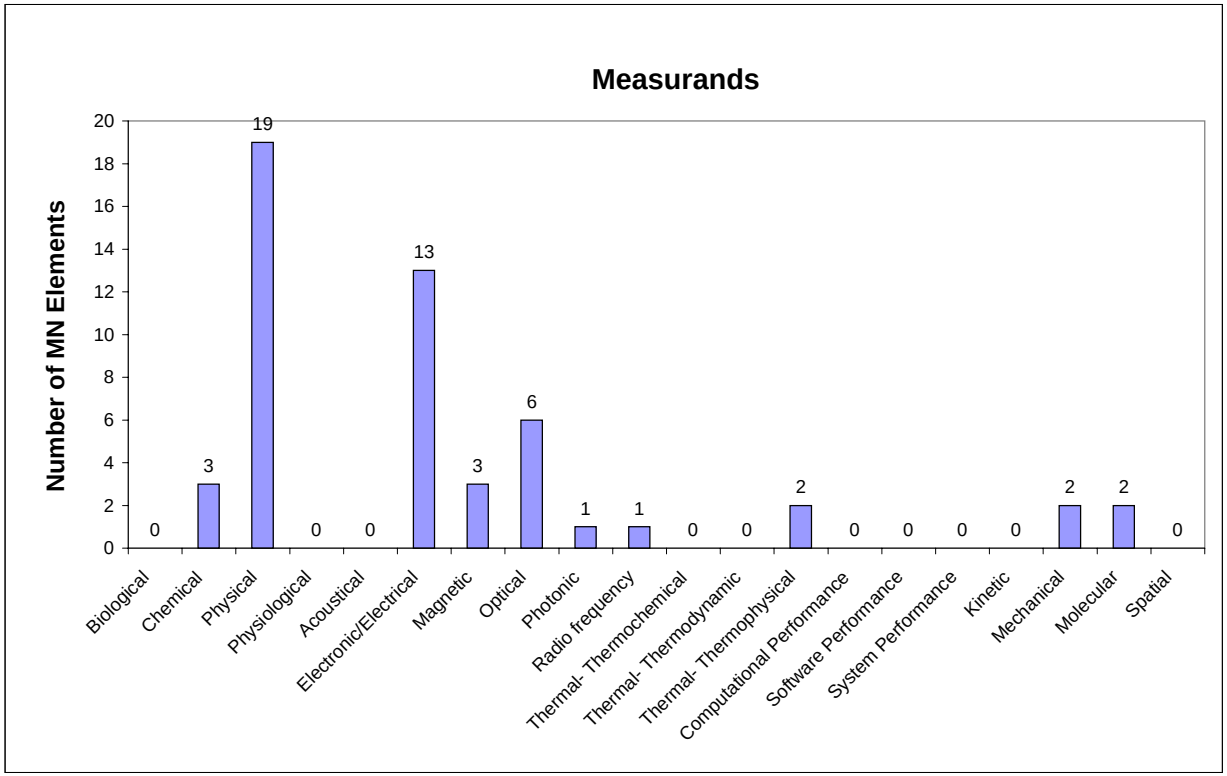

Exhibit 5.5: MN Distribution of Current Public/Private R&D Efforts in Electronics Semiconductor

Only Private Efforts Exist	Only Public Efforts Exist	Both Public and Private Efforts Exist	No Efforts Exist
4	2	15	31

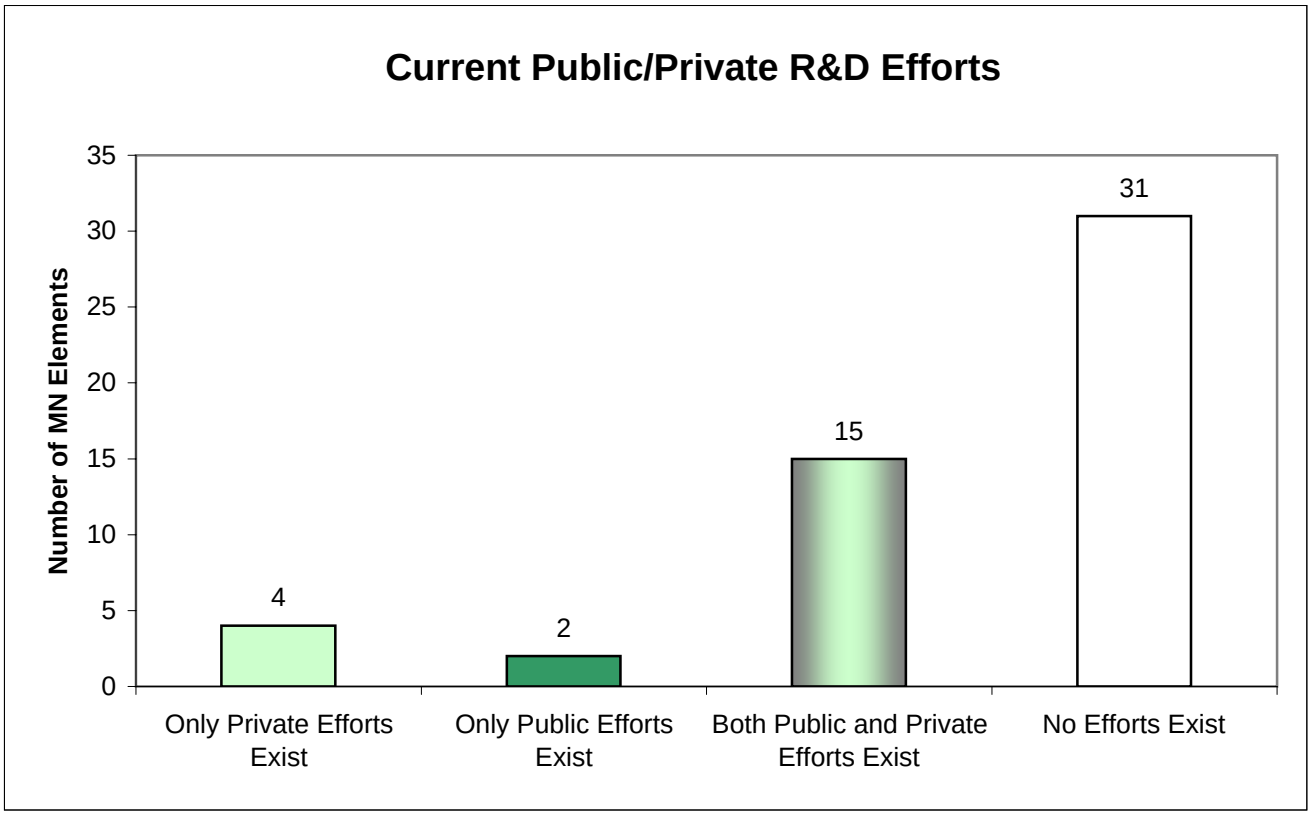

Exhibit 5.6: MN Distribution of TI as Measurement Technology in Electronics Semiconductor

Technology Innovation is a Measurement Innovation	Technology Innovation is not a Measurement Innovation
18	34

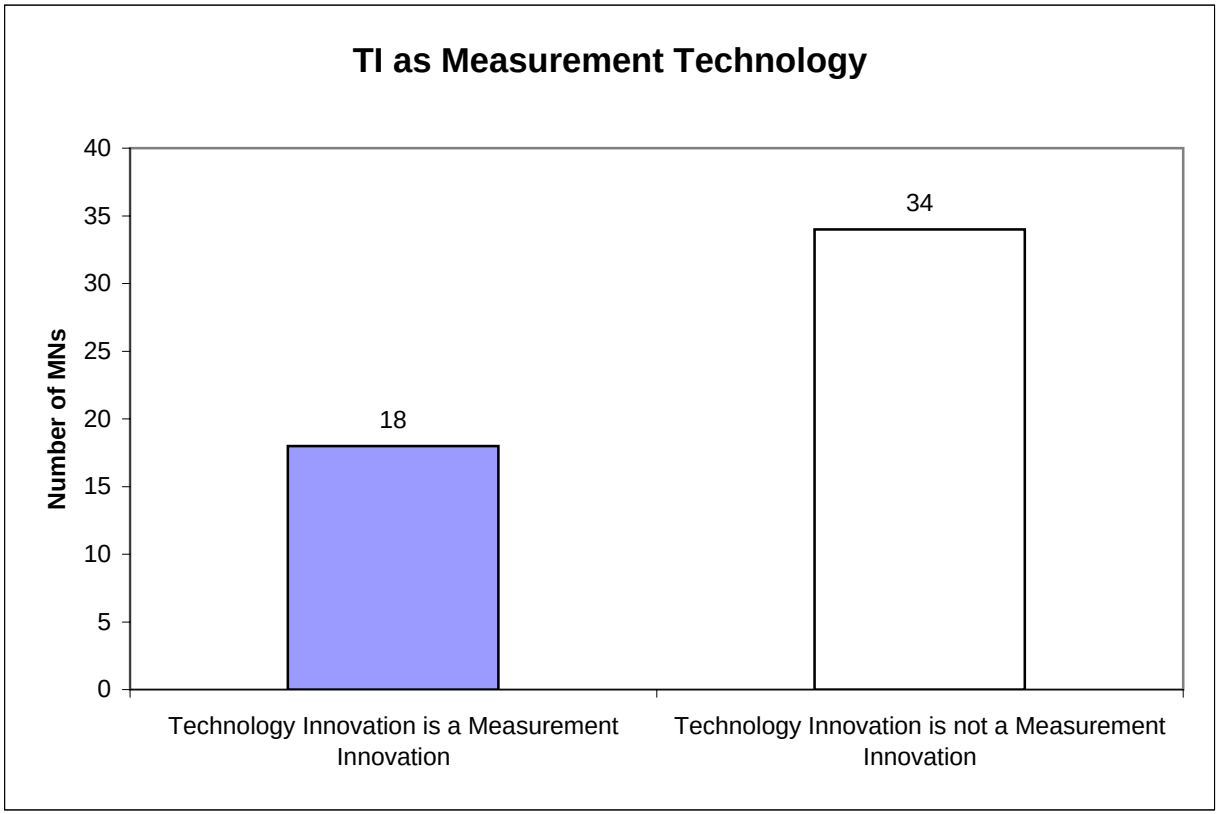

Exhibit 5.7: MN Distribution by Stage of Technological Innovation in Electronics Semiconductor

Applied Research	Production	Market	End-use	Total
44	6	1	1	52

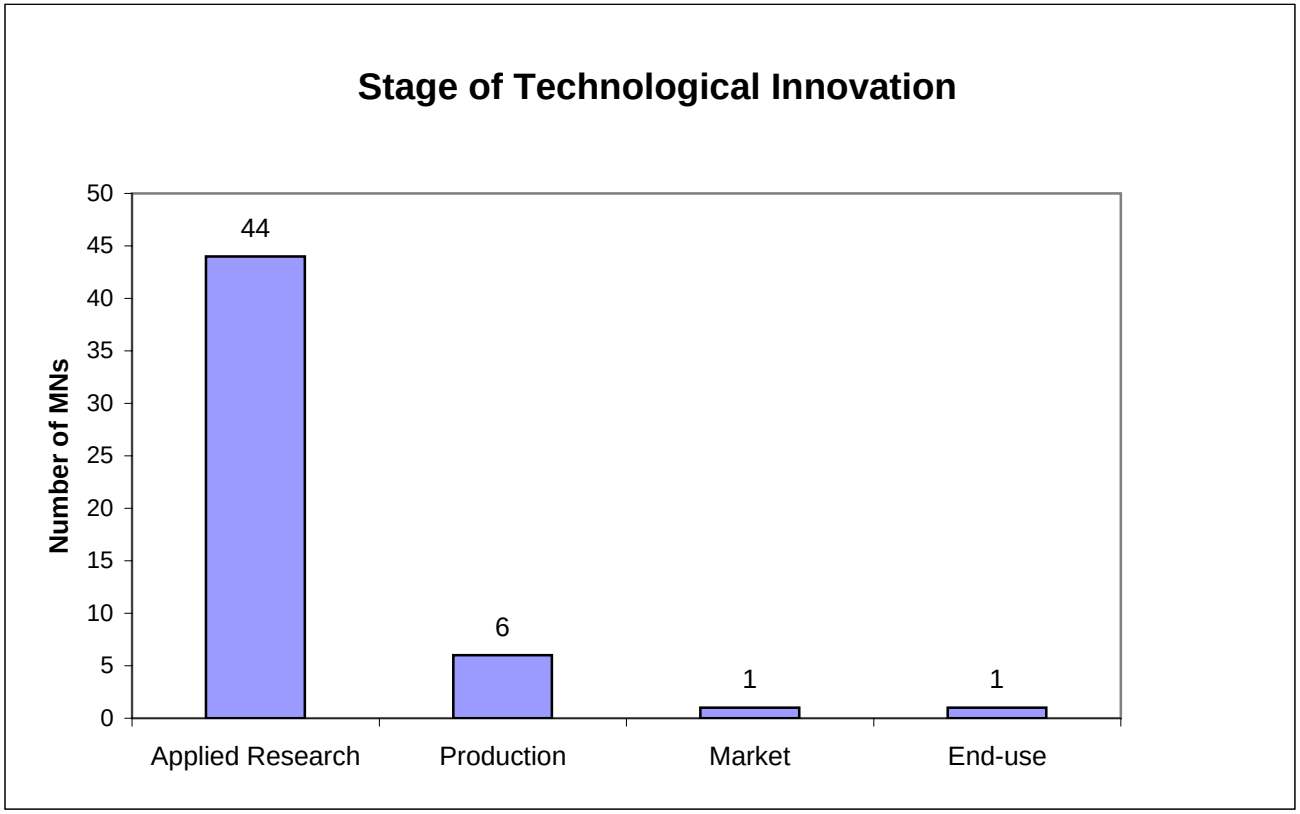

Exhibit 5.8: MN Distribution of Regulation as Driver/Barrier in Electronics Semiconductor

MN Driver	MN Barrier	No Impact
2	0	50

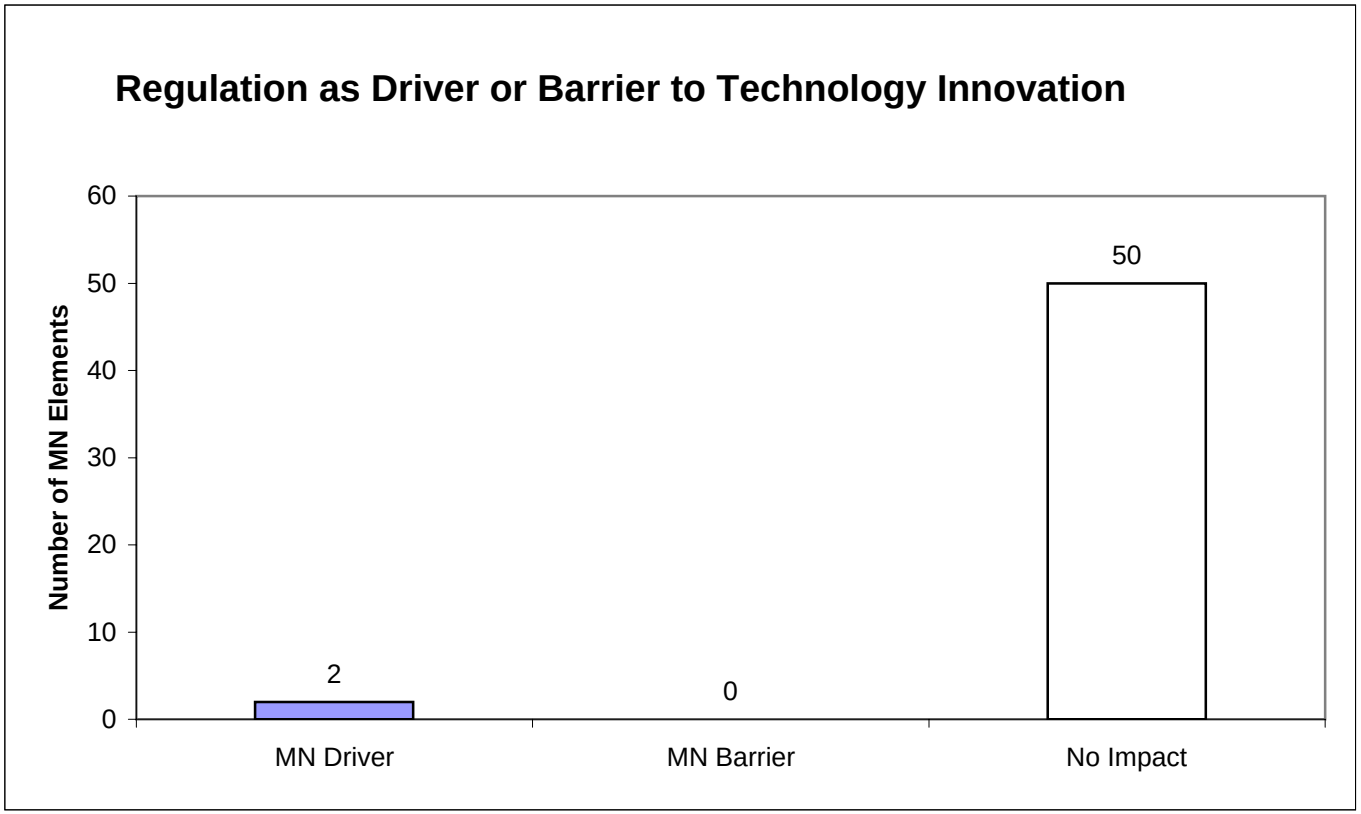

Exhibit 5.9: MN Correlation Matrix for Solution Providers and Measurement Barriers in Electronics Semiconductor

Solution Providers	Measurement Solution Barriers															
	Acceptability/Compatibility	Accessibility	Accuracy	Data, Data Collection and/or Retrieval	Destructive	Expense	Lack of fundamental knowledge	Multiple Solutions Exist	Not Standardized	Production Readiness	Reliability	Resolution	Small Market Demand	Speed	System-Level Problem	Workforce
Calibration laboratories			1			1										
Commercial calibration service providers																
Component suppliers																
Contractor R&D labs-for-hire			1				1									
Engineering management/consulting firms/A&E firms																
Government laboratories and agencies			24	3		4	10		2	1	7	14		9		
Independent testing/certification laboratories																
Industrial R&D laboratories			9	1		1	2		1	2	3	6		2		
Industry consortium/partnership	1	1	18	3	1	2	8		1		4	10		10		
Instrument suppliers	2		8	2		3	3		1	1	3	4		1		
Material suppliers			1	1							1	2		1		
National Measurement Institute	1	1	29	7	1	4	8		2	1	9	18		10		
Small business/inventors																
Software developers			2		1							1		1		
Standards development organizations (SDOs)									1							
Testing laboratories																
Universities		1	13	5		2	4		1	1	5	8		5		

Exhibit 5.10: MN Correlation Matrix for Measurement Barriers and Measurement Solutions in Electronics Semiconductor

	Measurement Solutions																								
	Infrastructure								Products													Services			
Measurement Solution Barriers	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Acceptability/Compatibility			1					1	1		1								1						
Accessibility									1			1													1
Accuracy			24	1	2	8	8	3	7	6	12	9	1	1	1			6	4			1	1		1
Data, Data Collection/and or Retrieval			1				2	2	3	3	2	3		2	1			1	1						1
Destructive			1		1					1															
Expense			5			4	1	1	1		3							2	1						
Lack of Fundamental Knowledge			9	2		4	1	1	2	4	7	1						1							
Multiple Solutions Exist																									
Not Standardized									1		1	1				1		1	1		1				
Production Readiness			2			1					1			1	1										
Reliability			5			3	4	2	3	2	3	3	1	2	1	1		2	1		1	1			
Resolution			17	1		7	3	2		6	7	6	1	1				2	3				1		
Small Market Demand																									
Speed			10		2	4	2	1		2	6	3						2	1						
System-Level Problem																									
Workforce																									

Exhibit 5.11: MN Correlation Matrix for Measurement Providers and Measurement Solutions in Electronics Semiconductor

	Measurement Solutions																									
	Infrastructure								Products														Services			
Measurement Solution Providers	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Calibration laboratories			1			1												1							
Commercial calibration service providers																									
Component suppliers																									
Contractor R&D labs-for-hire									1	1	1														
Engineering management/consulting firms/A&E firms																									
Government laboratories and agencies			23	2	1	10	6	1	2	6	9	7		3	1	1		5	4		1				
Independent testing/certification laboratories																									
Industrial R&D laboratories			8		1	2	2	1	1	1	2	7	1	1	1	1			3		1		1		
Industry consortium/partnership			16	1	2	7	2	1	3	3	11	3	1		1			3	1						1
Instrument suppliers			6			2	3	1	3	2	5	2		1					2						
Material suppliers			1			1	1	1		1		1													
National Measurement Institute			22	1	1	9	6	5	6	8	12	10	1	1	1			6	3			1	1		1
Small business/inventors																									
Software developers			1		1					2		1													
Standards development organizations (SDOs)												1						1							
Testing laboratories																									
Universities			10	1		4	2	1	2	4	5	6		3	2	1		4	3		1				1

Exhibit 5.12: MN Correlation Matrix for Stage of Technological Innovation and Measurement Barriers in Electronics Semiconductor

Stage of Technological Innovation	Measurement Solution Barriers															
	Acceptability/Compatibility	Accessibility	Accuracy	Data, Data Collection and/or Retrieval	Destructive	Expense	Lack of fundamental knowledge	Multiple Solutions Exist	Not Standardized	Production Readiness	Reliability	Resolution	Small Market Demand	Speed	System-Level Problem	Workforce
Applied Research	1		32	6	1	4	12		2	2	11	21		13		
Production	1	1	5	2		1	1				1	1				
Market									1							
End-use			1			1										

Exhibit 5.13: MN Correlation Matrix for Stage of Technological Innovation and Measurement Solutions in Electronics Semiconductor

	Measurement Solutions																								
	Infrastructure								Products														Services			
Stage of Technological Innovation	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Applied Research			27	2	2	11	7	4	5	9	15	11	1	3	1	1		4	5		1	1	1		
Production			3				1	1	2	1	1	1			1			1	1						1
Market												1						1							
End-use			1			1												1							

Exhibit 5.14: MN Correlation Matrix for Solution Providers and Stage of Technological Innovation in Electronics Semiconductor

Measurement Solution Providers	Stage of Technological Innovation			
	Applied Research	Production	Market	End-use
Calibration laboratories				1
Commercial calibration service providers				
Component suppliers				
Contractor R&D labs-for-hire	1			
Engineering management/consulting firms/A&E firms				
Government laboratories and agencies	29	3	1	1
Independent testing/certification laboratories				
Industrial R&D laboratories	13	3		
Industry consortium/partnership	19	3		
Instrument suppliers	9	1		
Material suppliers	2			
National Measurement Institute	31	5	1	1
Small business/inventors				
Software developers	2			
Standards development organizations (SDOs)			1	
Testing laboratories				
Universities	17	2		

Exhibit 5.15: MN Correlation Matrix for Stage of Technological Innovation and TI as Measurement Technology in Electronics Semiconductor

Stage of Technological Innovation	TI as Measurement Technology
Applied Research	17
Production	
Market	
End-use	1

Exhibit 5.16: MN Correlation Matrix for TI as Measurement Technology and Measurement Barriers in Electronics Semiconductor

Innovation Equivalency	Measurement Solution Barriers															
	Acceptability/Compatibility	Accessibility	Accuracy	Data, Data Collection and/or Retrieval	Destructive	Expense	Lack of fundamental knowledge	Multiple Solutions Exist	Not Standardized	Production Readiness	Reliability	Resolution	Small Market Demand	Speed	System-Level Problem	Workforce
Technology Innovation = Measurement Innovation			14	3		3	3		1	1	6	9		1		

Exhibit 5.17: MN Correlation Matrix for Solution Providers and TI as Measurement Technology in Electronics Semiconductor

Measurement Solution Providers	Technology Innovation = Measurement Innovation
Calibration laboratories	1
Commercial calibration service providers	
Component suppliers	
Contractor R&D labs-for-hire	1
Engineering management/consulting firms/A&E firms	
Government laboratories and agencies	11
Independent testing/certification laboratories	
Industrial R&D laboratories	6
Industry consortium/partnership	1
Instrument suppliers	5
Material suppliers	2
National Measurement Institute	13
Small business/inventors	
Software developers	1
Standards development organizations (SDOs)	
Testing laboratories	
Universities	7

Exhibit 5.18: MN Correlation Matrix for TI as Measurement Technology and Measurement Solutions in Electronics Semiconductor

	Measurement Solutions																								
	Infrastructure								Products													Services			
Innovation Equivalency	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Technology Innovation = Measurement Innovation			10			5	5	2	2	5	4	6		1		1		2	2		1	1	1		

Exhibit 5.19: MN Correlation Matrix for Regulation as Driver/Barrier and Measurement Solutions in Electronics Semiconductor

	Measurement Solutions																								
	Infrastructure								Products													Services			
Regulatory Issues	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Regulation is a Driver			1			1			1			1						1							1
Regulation is a Barrier																									

Exhibit 5.20: MN Correlation Matrix for Solution Providers and Regulation as Driver/Barrier in Electronics Semiconductor

Measurement Solution Providers	Regulation is a Driver	Regulation is a Barrier
Calibration laboratories	1	
Commercial calibration service providers		
Component suppliers		
Contractor R&D labs-for-hire		
Engineering management/consulting firms/A&E firms		
Government laboratories and agencies	1	
Independent testing/certification laboratories		
Industrial R&D laboratories		
Industry consortium/partnership	1	
Instrument suppliers		
Material suppliers		
National Measurement Institute	2	
Small business/inventors		
Software developers		
Standards development organizations (SDOs)		
Testing laboratories		
Universities	1	

U.S. Measurement System

Measurement Need (MN) Data Book

Chapter 6. Energy, Power, and Environment

(includes Fossil fuel, Hydrogen, Renewable, and Power Generation and Distribution)

Prepared by
Energetics Incorporated
for the
National Institute of Standards and Technology

April 2006

Reference List of MN Distribution Charts and MN Correlation Matrices

Exhibit 6.1: MN Distribution of Measurement Barriers in Energy, Power, and Environment

Acceptibility	Accessibility	Accuracy	Data, Data Collection & Retrieval	Destructive	Expense	Lack of Fundamental Knowledge	Multiple Solutions	Not Standardized	Production Readiness	Reliability	Resolution	Small market demand	Speed	Systems-level	Workforce	Total
1	1	14	15	1	0	7	1	9	1	7	3	0	2	0	0	62

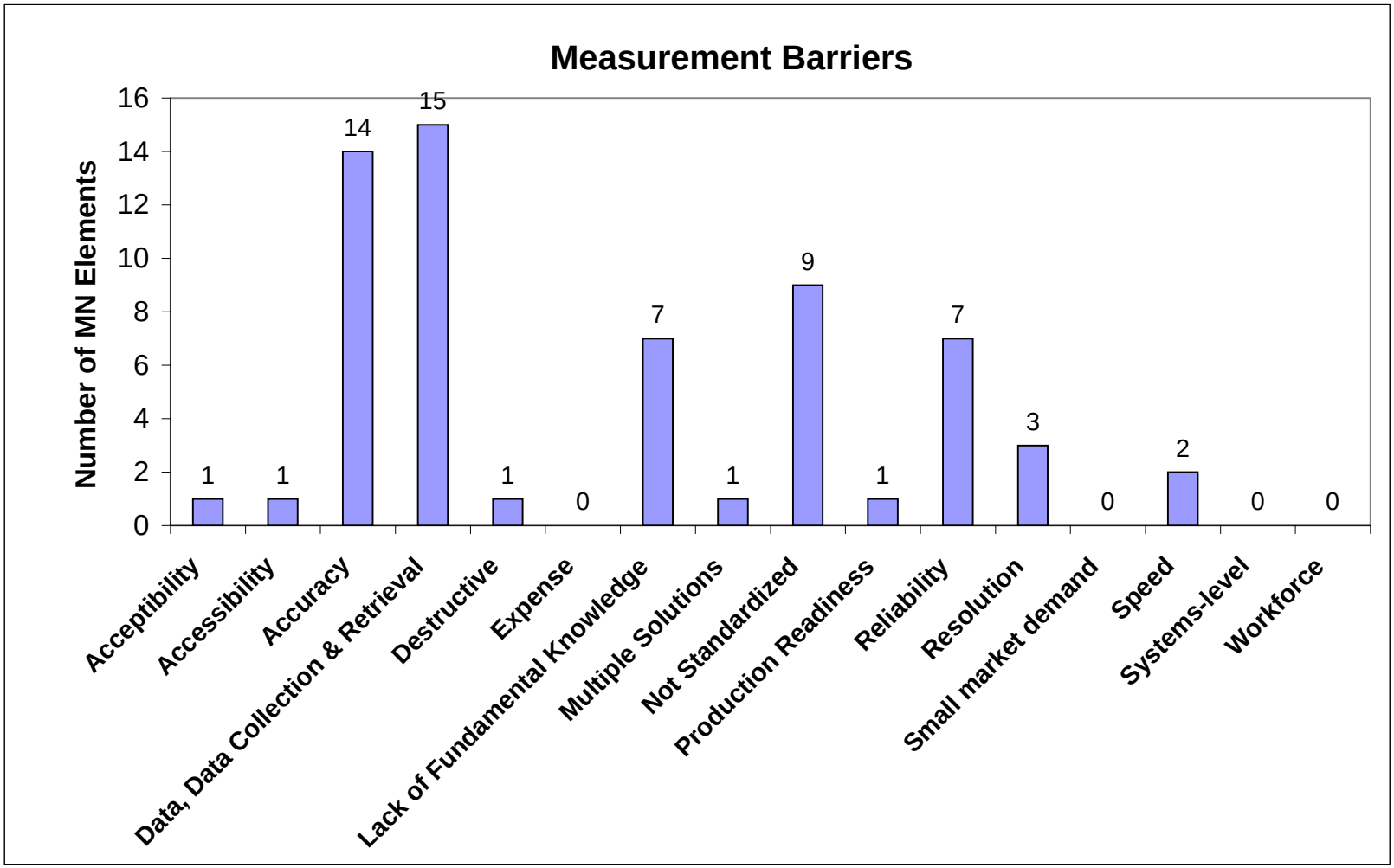

Exhibit 6.2: MN Distribution of Measurement Solution Providers in Energy, Power, and Environment

Calibration Laboratories	Commercial Calibration Service Providers	Component Suppliers	Contractor R&D Labs-for-Hire	Engineering Management/Consulting Firms/A&E Firms	Government Laboratories and Agencies	Independent Testing/Certification Laboratories	Industrial R&D Laboratories	Industry Consortium/ Partnership	Instrument Suppliers	Material Suppliers	National Measurement Institute	Small Business/Inventors	Software Developers	Standards Development Organizations (SDO)	Testing Laboratories	Universities	Total
3	1	1	0	0	18	2	10	2	3	2	20	0	1	3	0	8	74

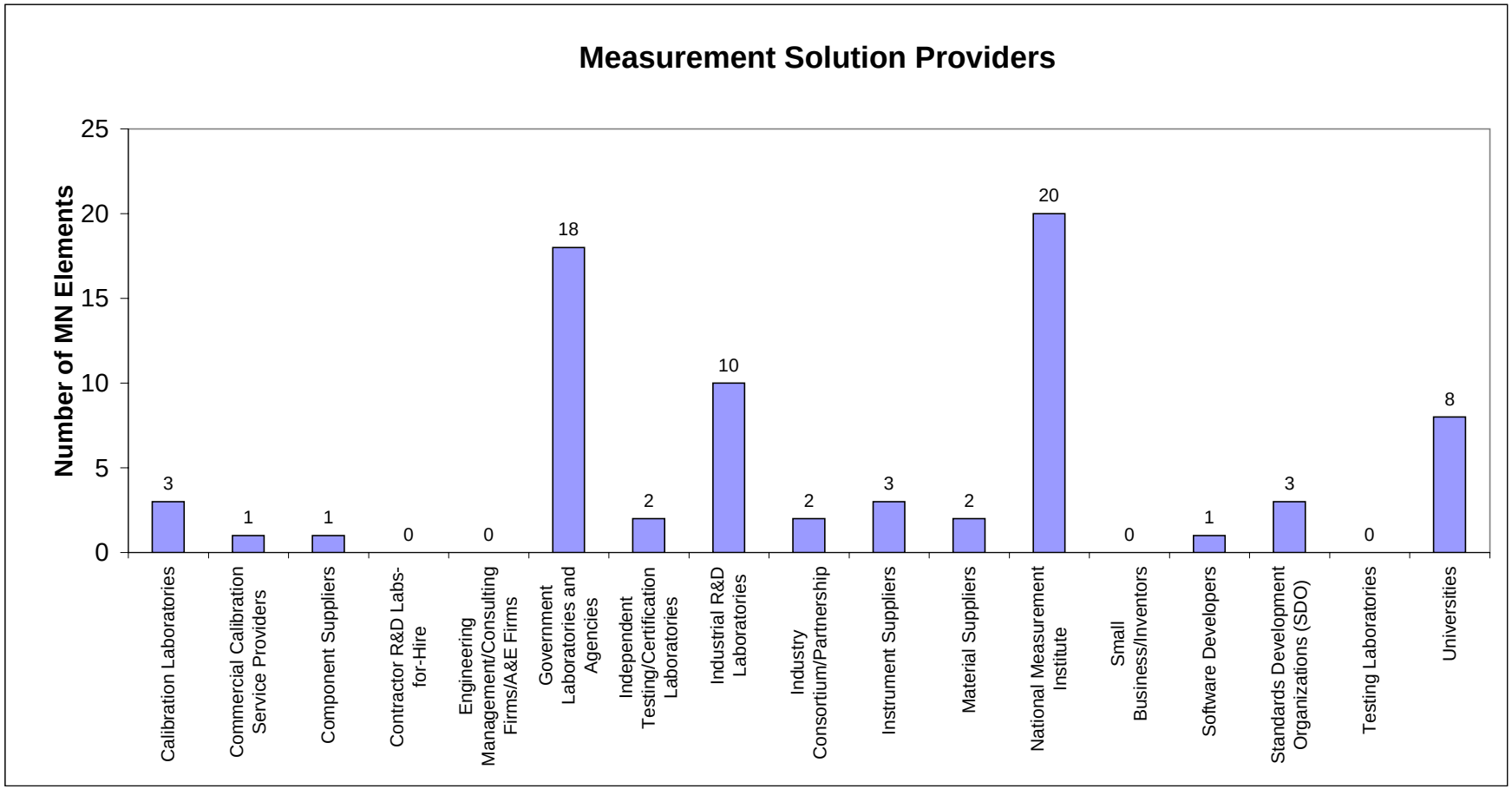

Exhibit 6.3: MN Distribution of Measurement Solutions in Energy, Power, and Environment

Infrastructure								Products												Services				
Coordination/Facilitation	Data Collection/Retrieval	Development - Measurement Technology	Fund-amental Knowledge	Protocols	Research - Measure-ment Science	Standards	User Facility	Calibration	Computational Methods	Measure-ment Instrument	Measure-ment Method	Metrics/Benchmarks	Raw Data	Reference Data	Software	Stability Tests	Standard/certified reference material	Test methods for production-scale measurements	Test methods or test data for consumer products	Validated (hardened) properties data	Calibration	Expert consultation	Intl Recognition	Third Party Verification	Total
2	1	7	3	1	5	7	3	7	6	2	6	2	4	3	0	0	2	6	1	1	1	0	1	1	72

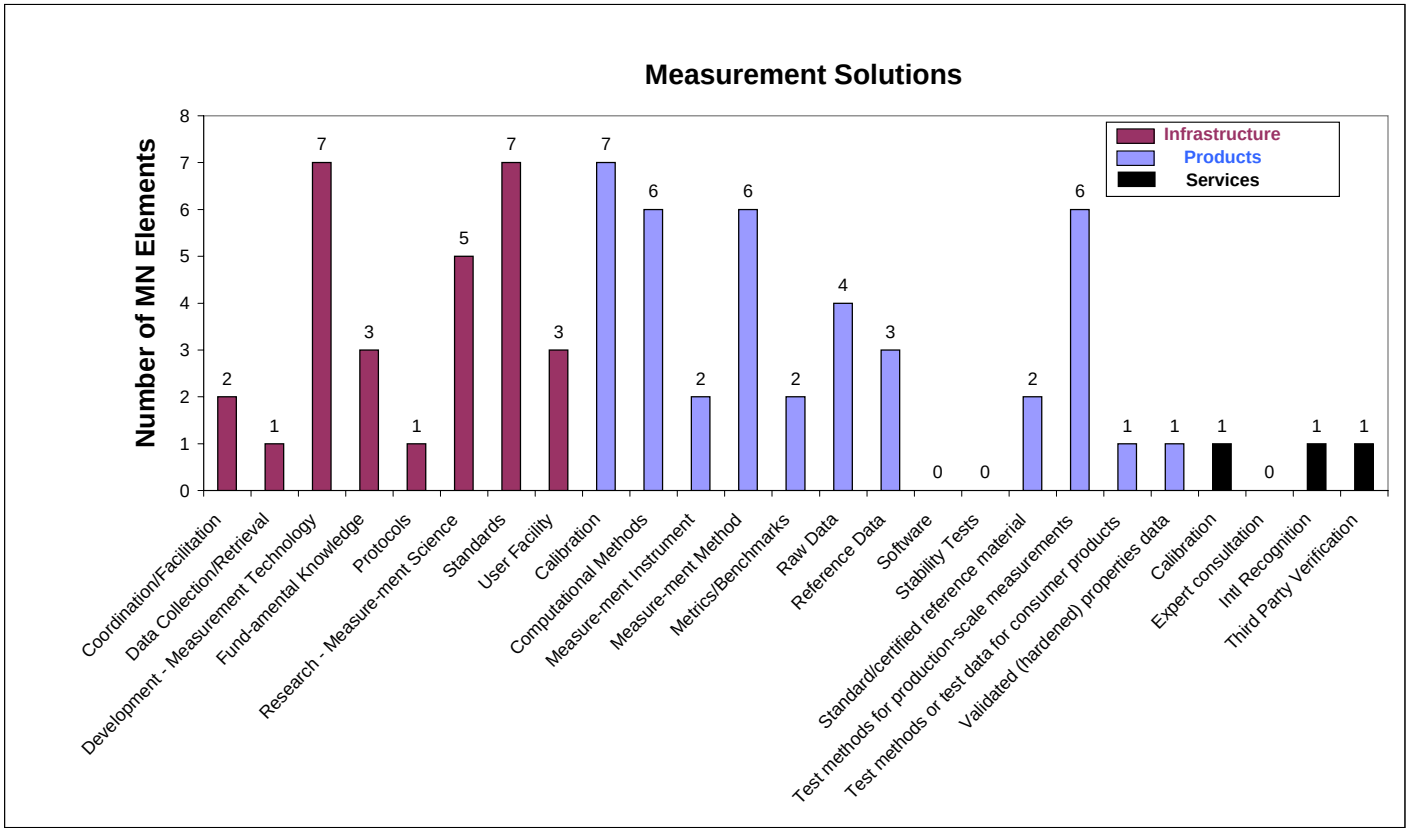

Exhibit 6.4: MN Distribution of Measurands in Energy, Power, and Environment

Classical				Functional									Performance			Structural				
Biological	Chemical	Physical	Physiological	Acoustical	Electronic/ Electrical	Magnetic	Optical	Photonic	Radio frequency	Thermal- Thermochemical	Thermal- Thermodynamic	Thermal- Thermophysical	Computational Performance	Software Performance	System Performance	Kinetic	Mechanical	Molecular	Spatial	Total
0	4	5	1	1	6	2	2	1	0	2	1	1	0	0	0	0	1	0	0	27

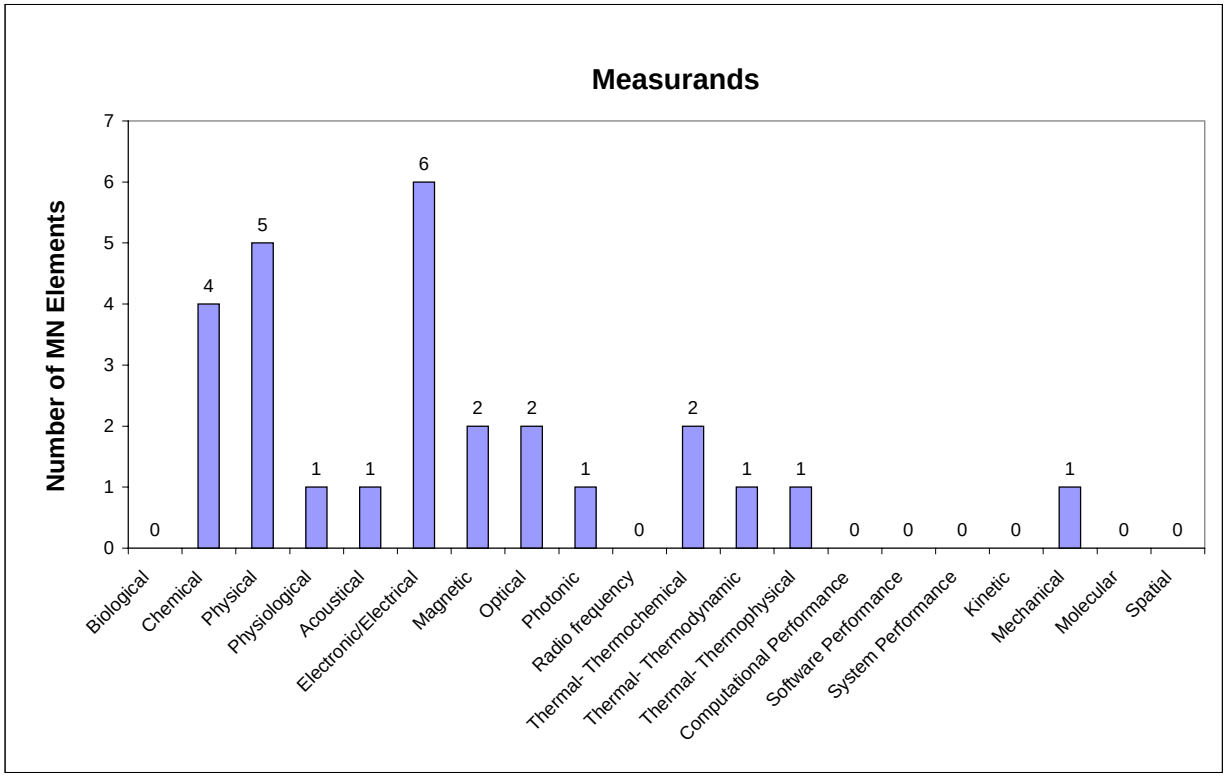

Exhibit 6.5: MN Distribution of Current Public/Private R&D Efforts in Energy, Power, and Environment

Only Private Efforts Exist	Only Public Efforts Exist	Both Public and Private Efforts Exist	No Efforts Exist
2	7	5	13

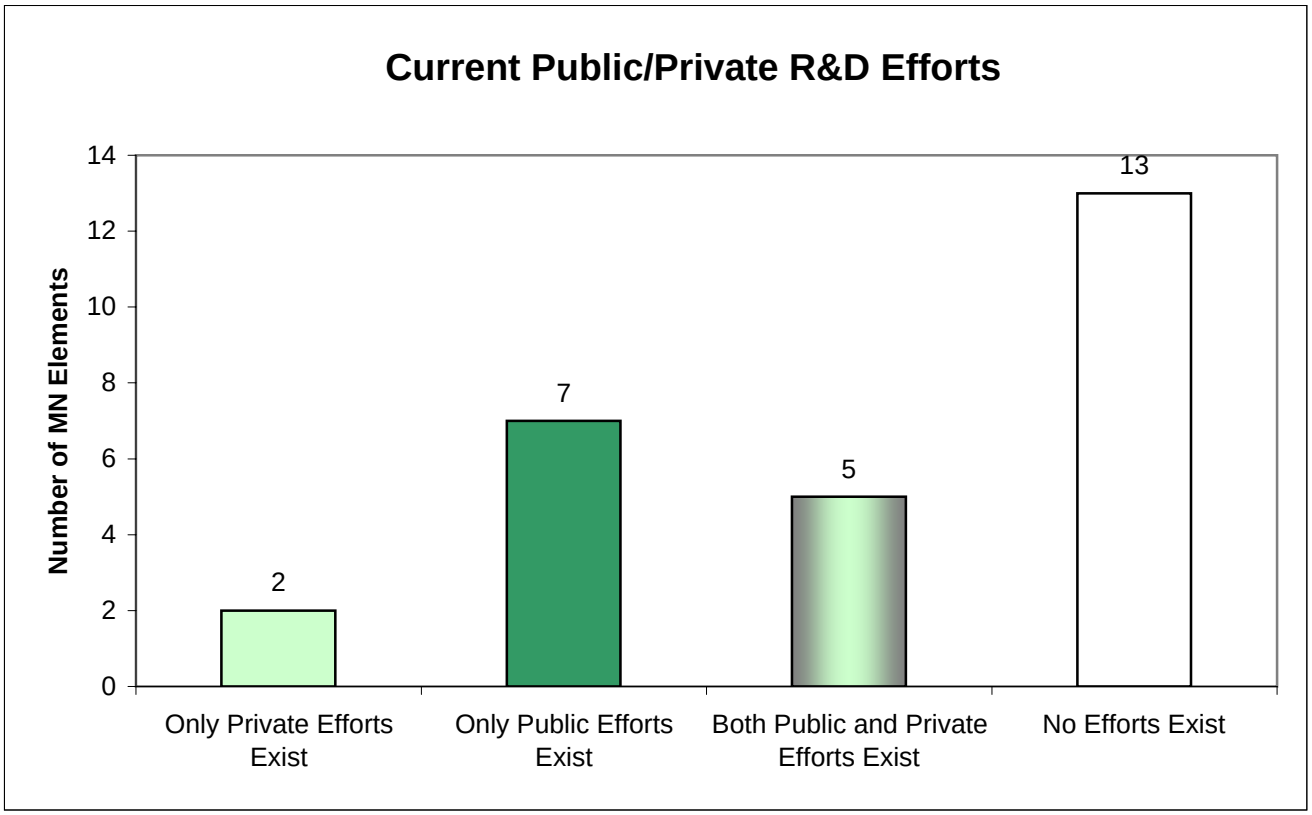

Exhibit 6.6: MN Distribution of TI as Measurement Technology in Energy, Power, and Environment

Technology Innovation is a Measurement Innovation	Technology Innovation is not a Measurement Innovation
11	16

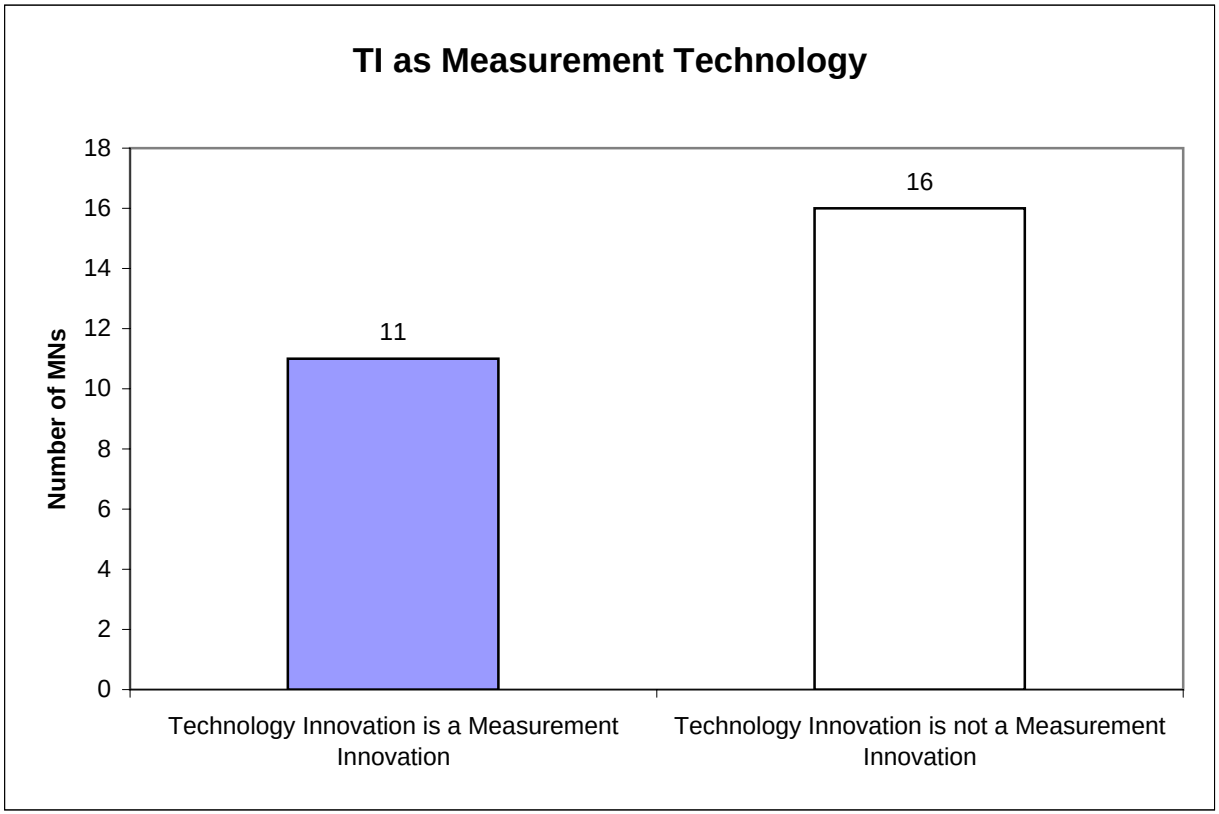

Exhibit 6.7: MN Distribution by Stage of Technological Innovation in Energy, Power, and Environment

Applied Research	Production	Market	End-use	Total
19	3	4	1	27

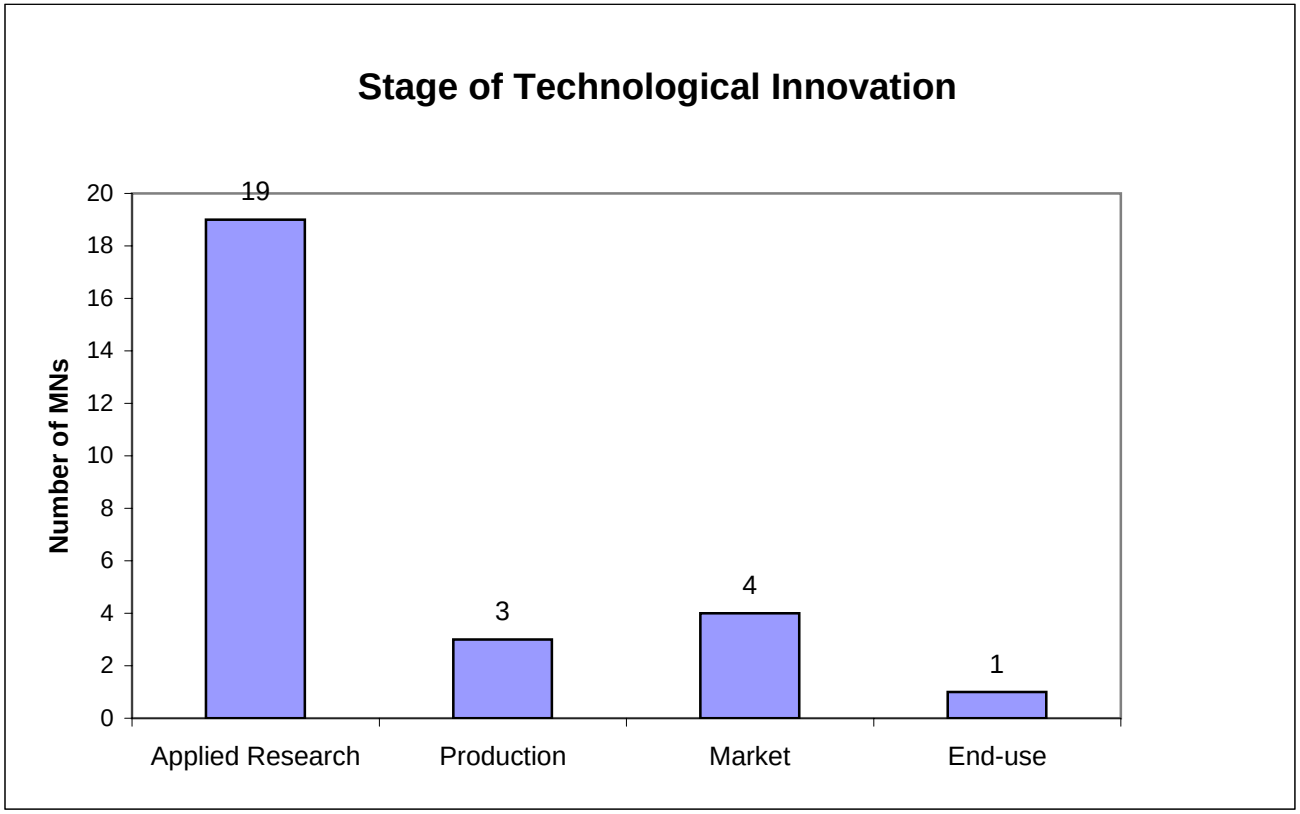

Exhibit 6.8: MN Distribution of Regulation as Driver/Barrier in Energy, Power, and Environment

MN Driver	MN Barrier	No Impact
0	2	25

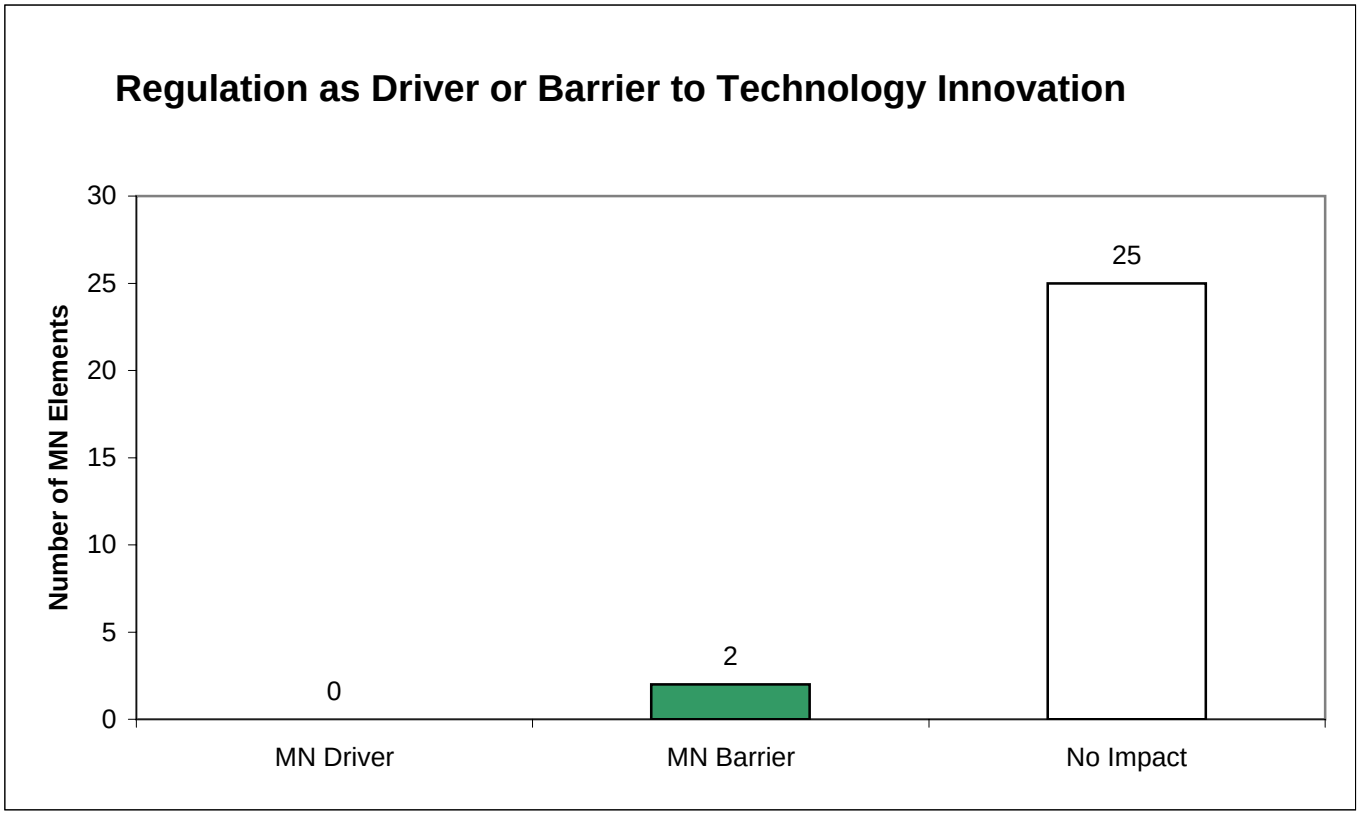

Exhibit 6.9: MN Correlation Matrix for Solution Providers and Measurement Barriers in Energy, Power, and Environment

Solution Providers	Measurement Solution Barriers															
	Acceptability/Compatibility	Accessibility	Accuracy	Data, Data Collection and/or Retrieval	Destructive	Expense	Lack of fundamental knowledge	Multiple Solutions Exist	Not Standardized	Production Readiness	Reliability	Resolution	Small Market Demand	Speed	System-Level Problem	Workforce
Calibration laboratories	1		3	1					1							
Commercial calibration service providers				1					1							
Component suppliers				1					1		1					
Contractor R&D labs-for-hire																
Engineering management/consulting firms/A&E firms																
Government laboratories and agencies		1	8	9	1		7	1	6	1	2	2		1		
Independent testing/certification laboratories	1		1	1					1		1					
Industrial R&D laboratories			4	6	1		5		3	1	2			1		
Industry consortium/partnership				2					1		1					
Instrument suppliers			2	2					2		1	1				
Material suppliers		1	1	1					1			1		1		
National Measurement Institute	1		11	11	1		5	1	5	1	6	2		2		
Small business/inventors																
Software developers				1					1			1				
Standards development organizations (SDOs)		1	2	1					2							
Testing laboratories																
Universities			5	6			2	1			3	1		1		

Exhibit 6.10: MN Correlation Matrix for Measurement Barriers and Measurement Solutions in Energy, Power, and Environment

	Measurement Solutions																							
	Infrastructure								Products													Services			
Measurement Solution Barriers	**Coordination/ facilitation**	**Data Collection/ Retrieval**	**Development for Measurement Technology**	**Fundamental Scientific Knowledge**	**Protocols**	**Research for Measurement Science**	**Standards**	**User Facility**	**Calibration Method**	**Computation Method**	**Measurement Instrument**	**Measurement Method**	**Metrics/ Benchmarks**	**Raw Properties Data**	**Reference Data**	**Software**	**Stability Tests**	**Standard/CRM**	**Test Methods - Production Scale**	**Test Methods - Consumer Products**	**Validated Data**	**Calibration Services**	**Expert Consultation**	**International Recognition**	**3rd Party Verification**
Acceptability/Compatibility							1		1															1	
Accessibility	1											1						1							
Accuracy	1		5	1	1	4	4	2	5	2		3		3				2	2			1		1	
Data, Data Collection/and or Retrieval	1	1	2	1		3	4	3	3	6	2	4	1	4	1			1	4	1	1				1
Destructive	1										1	1													
Expense																									
Lack of Fundamental Knowledge	1	1	3	2		2	1			1	1	1		1	2				3						
Multiple Solutions Exist			1					1	1																
Not Standardized	1			1	1	1	5		3	1	1	1	1	1	1			1	3	1	1				1
Production Readiness			1	1															1						
Reliability			3	1	1	2	3		3	2		1		1				1	2						1
Resolution			1	1				2	1	2		1		1											
Small Market Demand																									
Speed								1		1		2													
System-Level Problem																									
Workforce																									

Exhibit 6.11: MN Correlation Matrix for Measurement Providers and Measurement Solutions in Energy, Power, and Environment

	Measurement Solutions																									
	Infrastructure								Products														Services			
Measurement Solution Providers	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Calibration laboratories							2		1					1					1			1		1	
Commercial calibration service providers									1		1				1										
Component suppliers							1												1						1
Contractor R&D labs-for-hire																									
Engineering management/consulting firms/A&E firms																									
Government laboratories and agencies	2	1	6	3		3	3	2	4	2	2	3	1	2	3			1	4	1	1	1			
Independent testing/certification laboratories							2		1										1					1	1
Industrial R&D laboratories	1	1	2	2		4	2			2	1	2	1	1				1	3	1	1				
Industry consortium/partnership							1			1		1	1						1						1
Instrument suppliers			1	1		1	1		2	1				1					1						
Material suppliers	1							1		1		2						1							
National Measurement Institute	1		6	1	1	3	6	3	6	4	2	5	1	3	3			1	4	1	1	1		1	
Small business/inventors																									
Software developers				1					1	1															
Standards development organizations (SDOs)	1					1						1	1					1	1						
Testing laboratories																									
Universities		1	3	1		2	1	2	2	5		3	1	2				1							

Exhibit 6.12: MN Correlation Matrix for Stage of Technological Innovation and Measurement Barriers in Energy, Power, and Environment

Stage of Technological Innovation	Measurement Solution Barriers															
	Acceptability/Compatibility	Accessibility	Accuracy	Data, Data Collection and/or Retrieval	Destructive	Expense	Lack of fundamental knowledge	Multiple Solutions Exist	Not Standardized	Production Readiness	Reliability	Resolution	Small Market Demand	Speed	System-Level Problem	Workforce
Applied Research			9	12	1		6	1	6		5	3		2		
Production		1	2				1		1	1	1					
Market	1		2	3					1							
End-use			1						1		1					

Exhibit 6.13: MN Correlation Matrix for Stage of Technological Innovation and Measurement Solutions in Energy, Power, and Environment

	Measurement Solutions																								
	Infrastructure								Products													Services			
Stage of Technological Innovation	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Applied Research	1	1	6	2		4	4	3	5	5	2	4	1	4	3			1	4						1
Production	1		1	1								1						1	1			1			
Market						1	2		1	1		1	1						1	1	1			1	
End-use					1		1		1																

Exhibit 6.14: MN Correlation Matrix for Solution Providers and Stage of Technological Innovation in Energy, Power, and Environment

Measurement Solution Providers	Stage of Technological Innovation			
	Applied Research	Production	Market	End-use
Calibration laboratories	1	1	1	
Commercial calibration service providers	1			
Component suppliers	1			
Contractor R&D labs-for-hire				
Engineering management/consulting firms/A&E firms				
Government laboratories and agencies	13	3	2	
Independent testing/certification laboratories	1		1	
Industrial R&D laboratories	7	1	2	
Industry consortium/partnership	1		1	
Instrument suppliers	3			
Material suppliers	1	1		
National Measurement Institute	14	2	3	1
Small business/inventors				
Software developers	1			
Standards development organizations (SDOs)	1	1	1	
Testing laboratories				
Universities	7		1	

Exhibit 6.15: MN Correlation Matrix for Stage of Technological Innovation and TI as Measurement Technology in Energy, Power, and Environment

Stage of Technological Innovation	TI as Measurement Technology
Applied Research	9
Production	1
Market	1
End-use	

Exhibit 6.16: MN Correlation Matrix for TI as Measurement Technology and Measurement Barriers in Energy, Power, and Environment

	Measurement Solution Barriers															
Innovation Equivalency	**Acceptability/Compatibility**	**Accessibility**	**Accuracy**	**Data, Data Collection and/or Retrieval**	**Destructive**	**Expense**	**Lack of fundamental knowledge**	**Multiple Solutions Exist**	**Not Standardized**	**Production Readiness**	**Reliability**	**Resolution**	**Small Market Demand**	**Speed**	**System-Level Problem**	**Workforce**
Technology Innovation = Measurement Innovation	1		6	5			2		4		2	2		2		

Exhibit 6.17: MN Correlation Matrix for Solution Providers and TI as Measurement Technology in Energy, Power, and Environment

Measurement Solution Providers	Technology Innovation = Measurement Innovation
Calibration laboratories	3
Commercial calibration service providers	1
Component suppliers	
Contractor R&D labs-for-hire	
Engineering management/consulting firms/A&E firms	
Government laboratories and agencies	7
Independent testing/certification laboratories	1
Industrial R&D laboratories	2
Industry consortium/partnership	
Instrument suppliers	3
Material suppliers	1
National Measurement Institute	10
Small business/inventors	
Software developers	1
Standards development organizations (SDOs)	
Testing laboratories	
Universities	2

Exhibit 6.18: MN Correlation Matrix for TI as Measurement Technology and Measurement Solutions in Energy, Power, and Environment

	Measurement Solutions																								
	Infrastructure								Products														Services			
Innovation Equivalency	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Technology Innovation = Measurement Innovation			2	1		2	4	1	5	2	1	2		1	2				2			1		1	

Exhibit 6.19: MN Correlation Matrix for Regulation as Driver/Barrier and Measurement Solutions in Energy, Power, and Environment

	Measurement Solutions																							
	Infrastructure								Products													Services			
Regulatory Issues	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Regulation is a Driver																									
Regulation is a Barrier							2		1					1					1					1	

Exhibit 6.20: MN Correlation Matrix for Solution Providers and Regulation as Driver/Barrier in Energy, Power, and Environment

Measurement Solution Providers	Regulation is a Driver	Regulation is a Barrier
Calibration laboratories		2
Commercial calibration service providers		
Component suppliers		
Contractor R&D labs-for-hire		
Engineering management/consulting firms/A&E firms		
Government laboratories and agencies		
Independent testing/certification laboratories		1
Industrial R&D laboratories		
Industry consortium/partnership		
Instrument suppliers		1
Material suppliers		
National Measurement Institute		2
Small business/inventors		
Software developers		
Standards development organizations (SDOs)		
Testing laboratories		
Universities		

U.S. Measurement System

Measurement Need (MN) Data Book

Chapter 7. Healthcare

(includes Bioimaging and Informatics, Clinical Diagnostics, Health and Safety, and Pharmaceuticals)

Prepared by
Energetics Incorporated
for the
National Institute of Standards and Technology

April 2006

Reference List of MN Distribution Charts and MN Correlation Matrices

Exhibit 7.1: MN Distribution of Measurement Barriers in Healthcare

Acceptibility	Accessibility	Accuracy	Data, Data Collection & Retrieval	Destructive	Expense	Lack of Fundamental Knowledge	Multiple Solutions	Not Standardized	Production Readiness	Reliability	Resolution	Small market demand	Speed	Systems-level	Workforce	Total
5	1	50	23	1	6	27	4	23	1	23	13	0	4	3	1	185

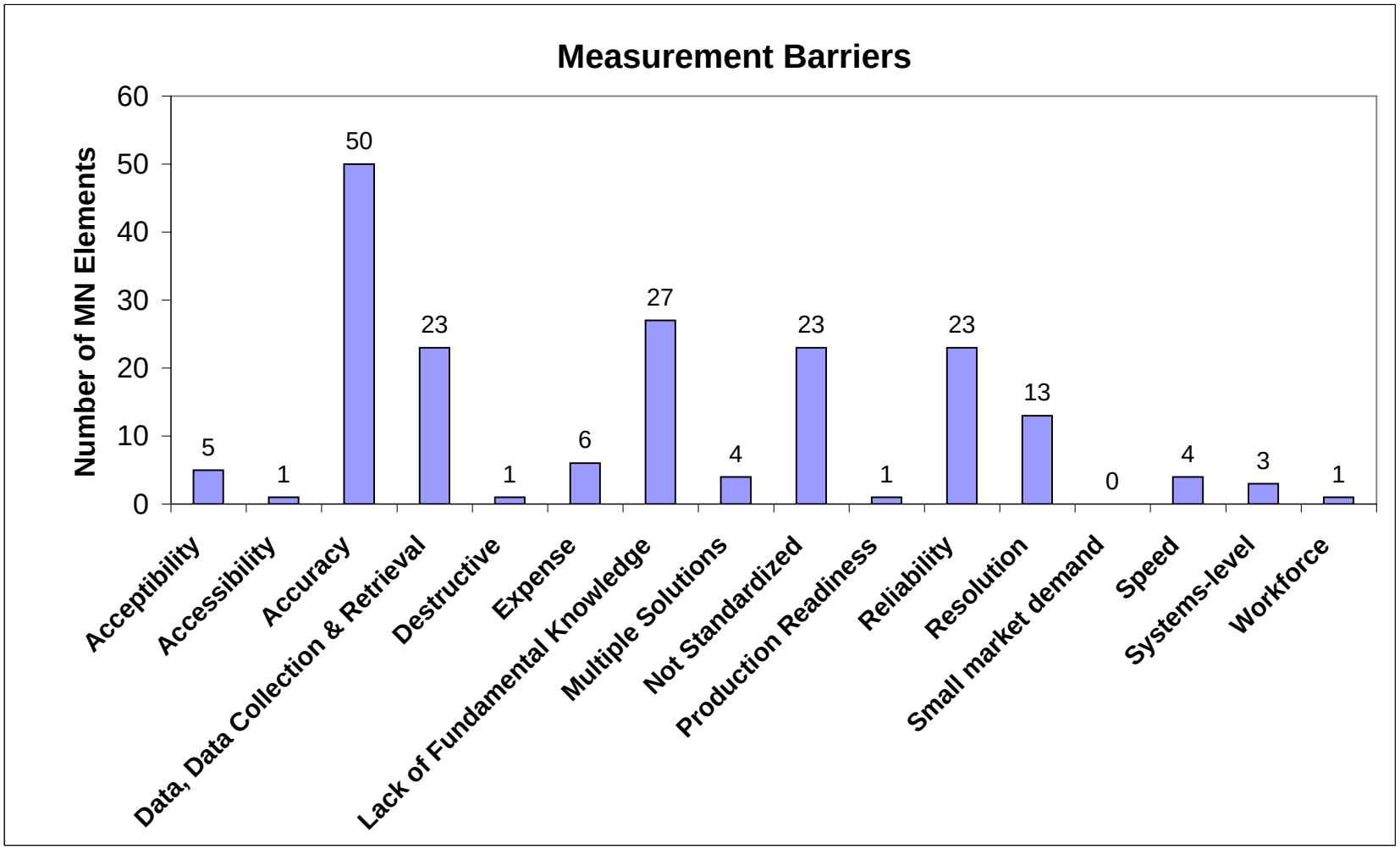

Exhibit 7.2: MN Distribution of Measurement Solution Providers in Healthcare

Calibration Laboratories	Commercial Calibration Service Providers	Component Suppliers	Contractor R&D Labs-for-Hire	Engineering Management/Consulting Firms/A&E Firms	Government Laboratories and Agencies	Independent Testing/Certification Laboratories	Industrial R&D Laboratories	Industry Consortium/ Partnership	Instrument Suppliers	Material Suppliers	National Measurement Institute	Small Business/Inventors	Software Developers	Standards Development Organizations (SDO)	Testing Laboratories	Universities	Total
1	0	2	0	1	55	2	25	16	16	2	59	0	2	11	1	27	220

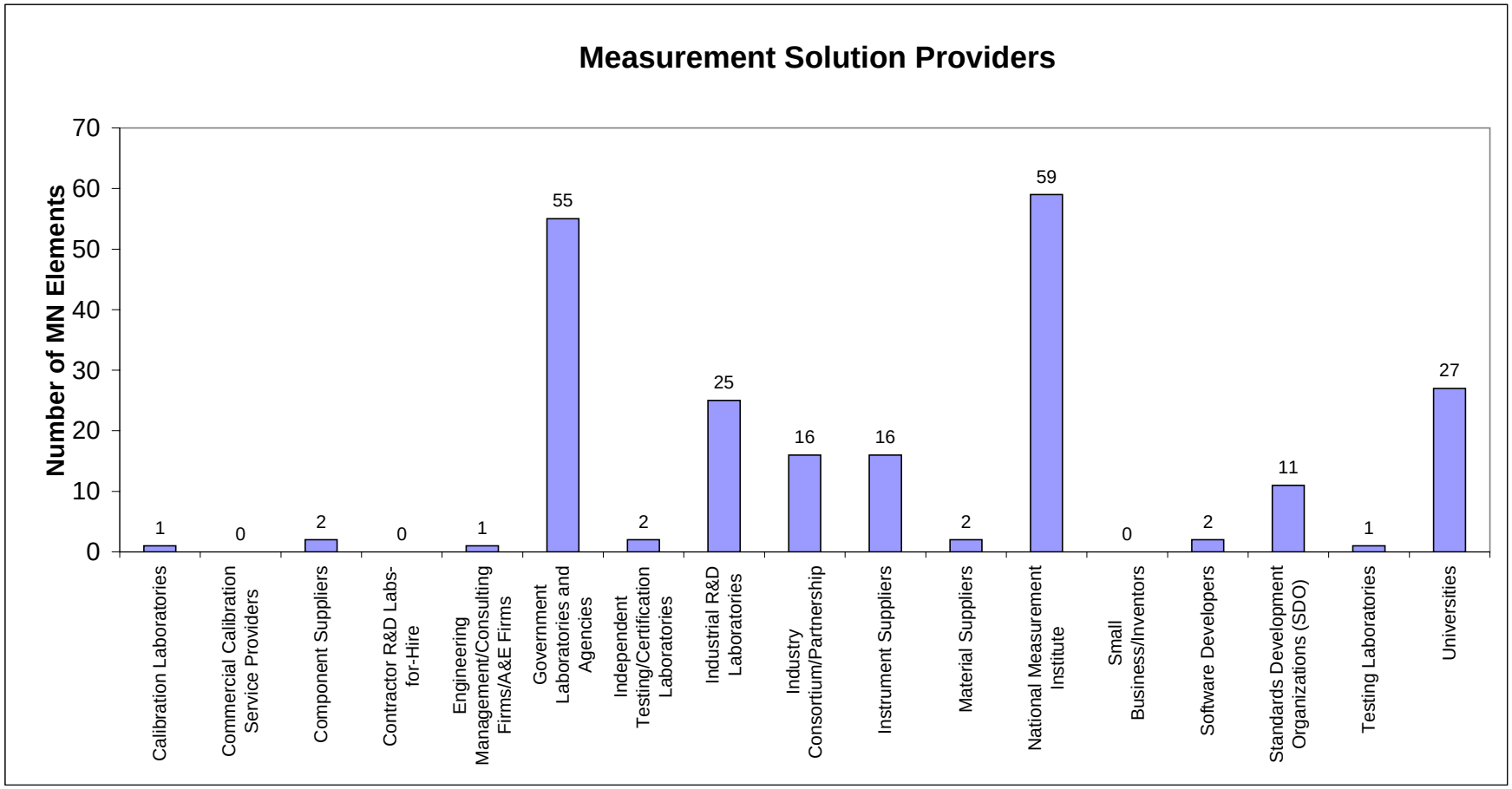

Exhibit 7.3: MN Distribution of Measurement Solutions in Healthcare

Infrastructure								Products												Services				
Coordination/Facilitation	Data Collection/Retrieval	Development - Measurement Technology	Fund-amental Knowledge	Protocols	Research - Measure-ment Science	Standards	User Facility	Calibration	Computational Methods	Measure-ment Instrument	Measure-ment Method	Metrics/Benchmarks	Raw Data	Reference Data	Software	Stability Tests	Standard/certified reference material	Test methods for production-scale measurements	Test methods or test data for consumer products	Validated (hardened) properties data	Calibration	Expert consultation	Intl Recognition	Third Party Verification	Total
2	5	24	7	16	14	28	2	8	10	10	25	10	4	12	5	1	14	7	6	2	0	0	0	1	213

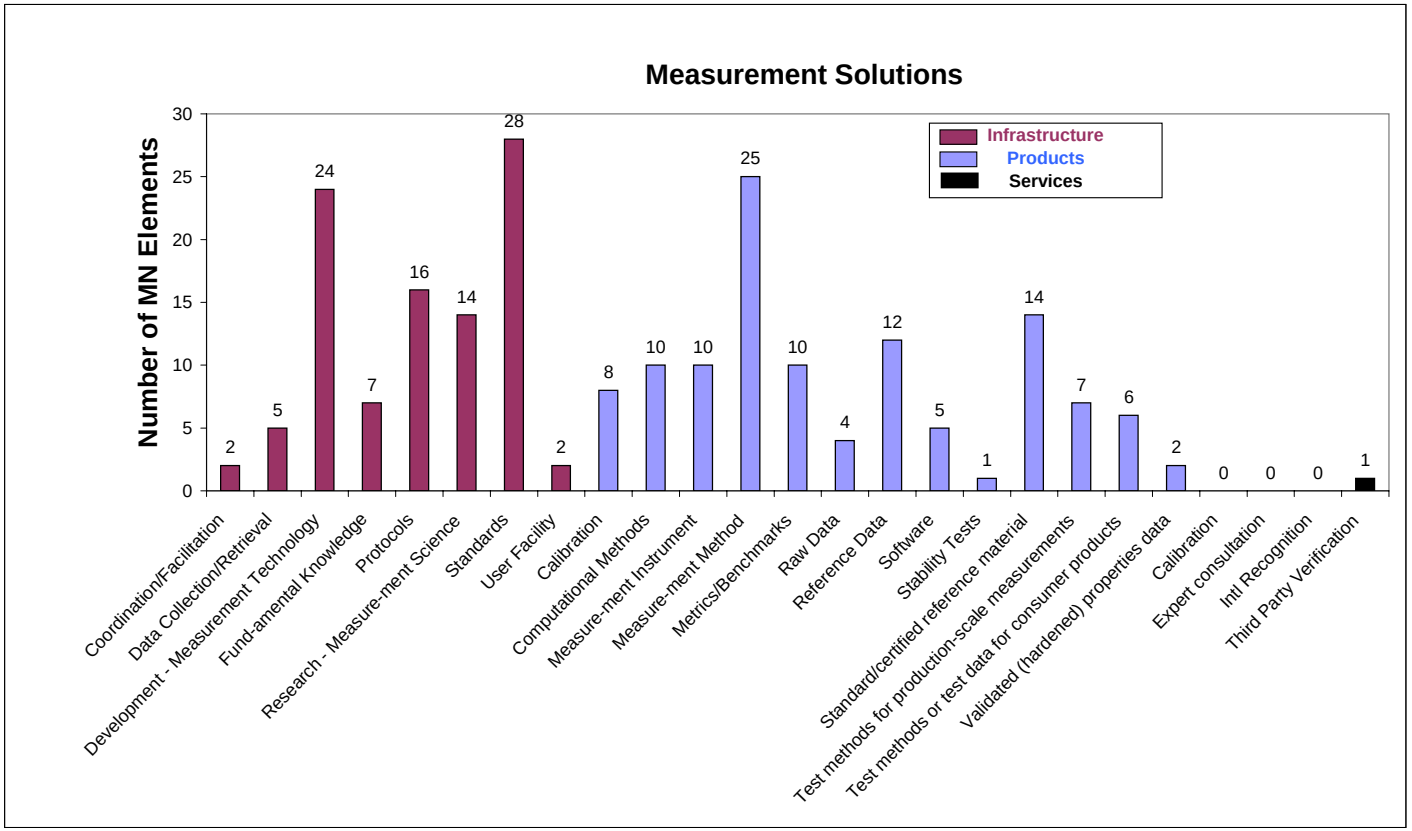

Exhibit 7.4: MN Distribution of Measurands in Healthcare

Classical				Functional									Performance			Structural				
Biological	Chemical	Physical	Physiological	Acoustical	Electronic/ Electrical	Magnetic	Optical	Photonic	Radio frequency	Thermal- Thermochemical	Thermal- Thermodynamic	Thermal- Thermophysical	Computational Performance	Software Performance	System Performance	Kinetic	Mechanical	Molecular	Spatial	Total
23	9	8	4	0	3	6	5	3	1	0	2	1	1	4	4	0	2	1	0	77

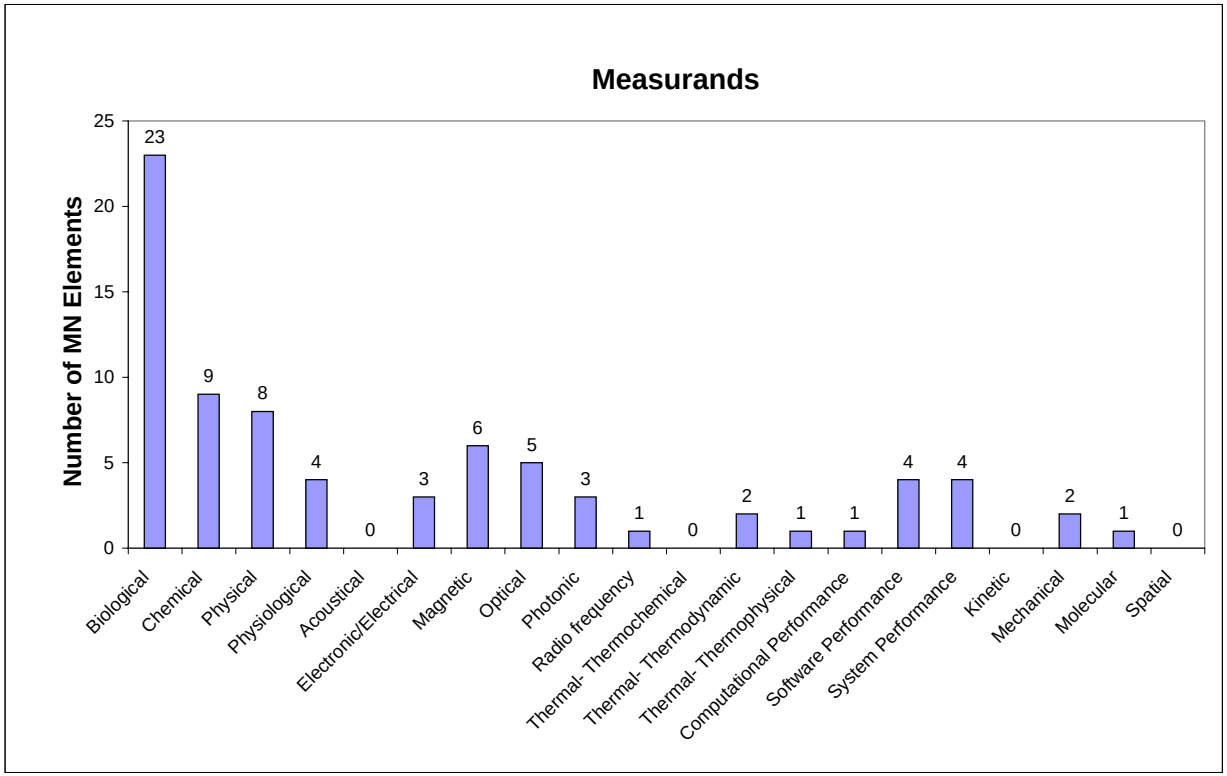

Exhibit 7.5: MN Distribution of Current Public/Private R&D Efforts in Healthcare

Only Private Efforts Exist	Only Public Efforts Exist	Both Public and Private Efforts Exist	No Efforts Exist
3	11	24	39

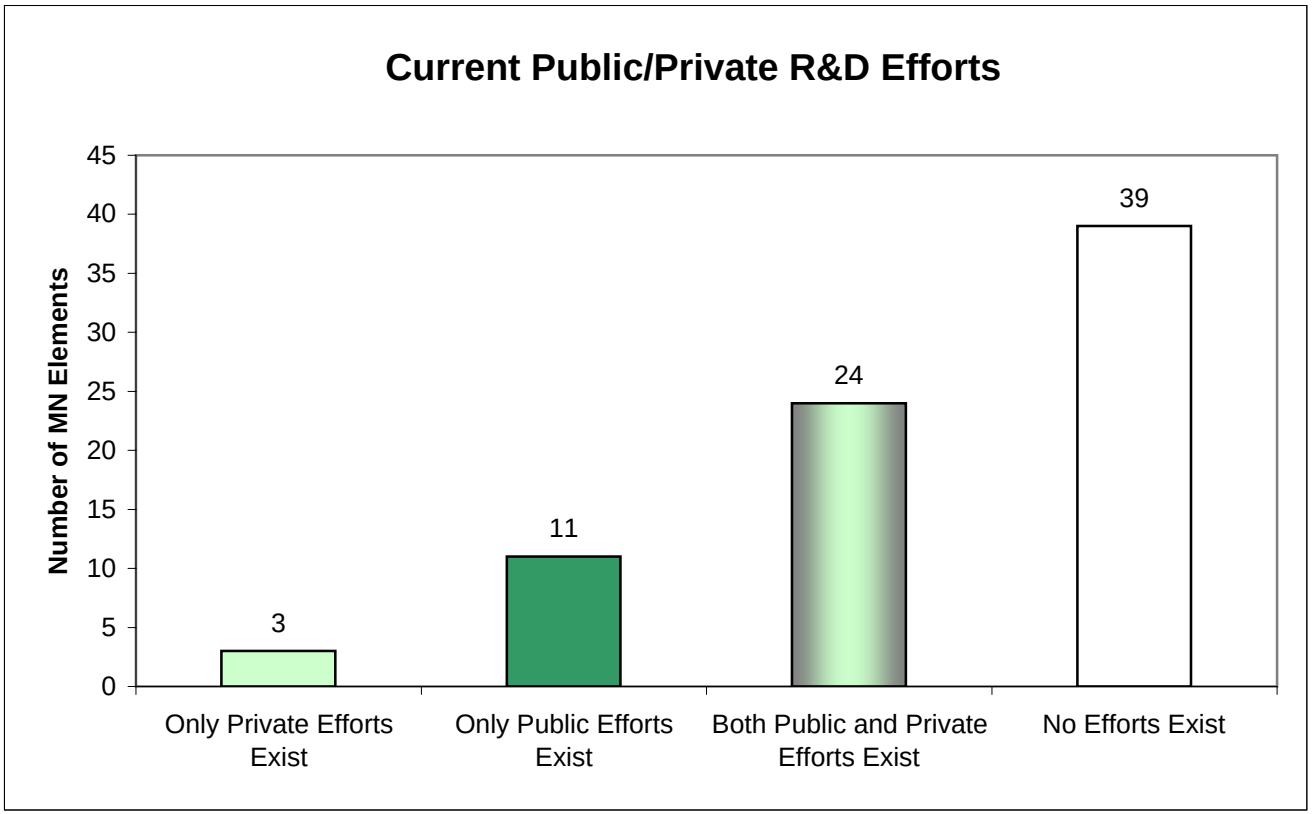

Exhibit 7.6: MN Distribution of TI as Measurement Technology in Healthcare

Technology Innovation is a Measurement Innovation	Technology Innovation is not a Measurement Innovation
47	30

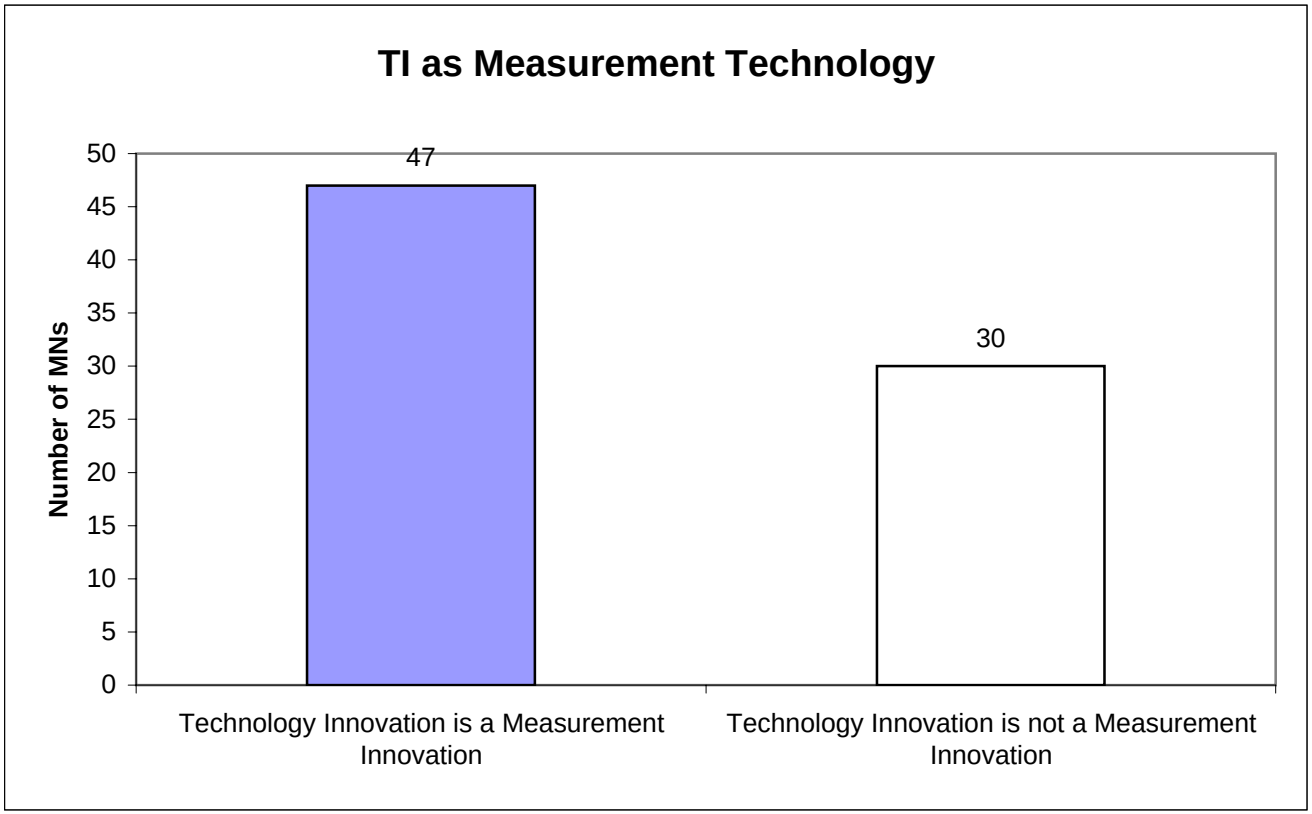

Exhibit 7.7: MN Distribution by Stage of Technological Innovation in Healthcare

Applied Research	Production	Market	End-use	Total
52	6	16	3	77

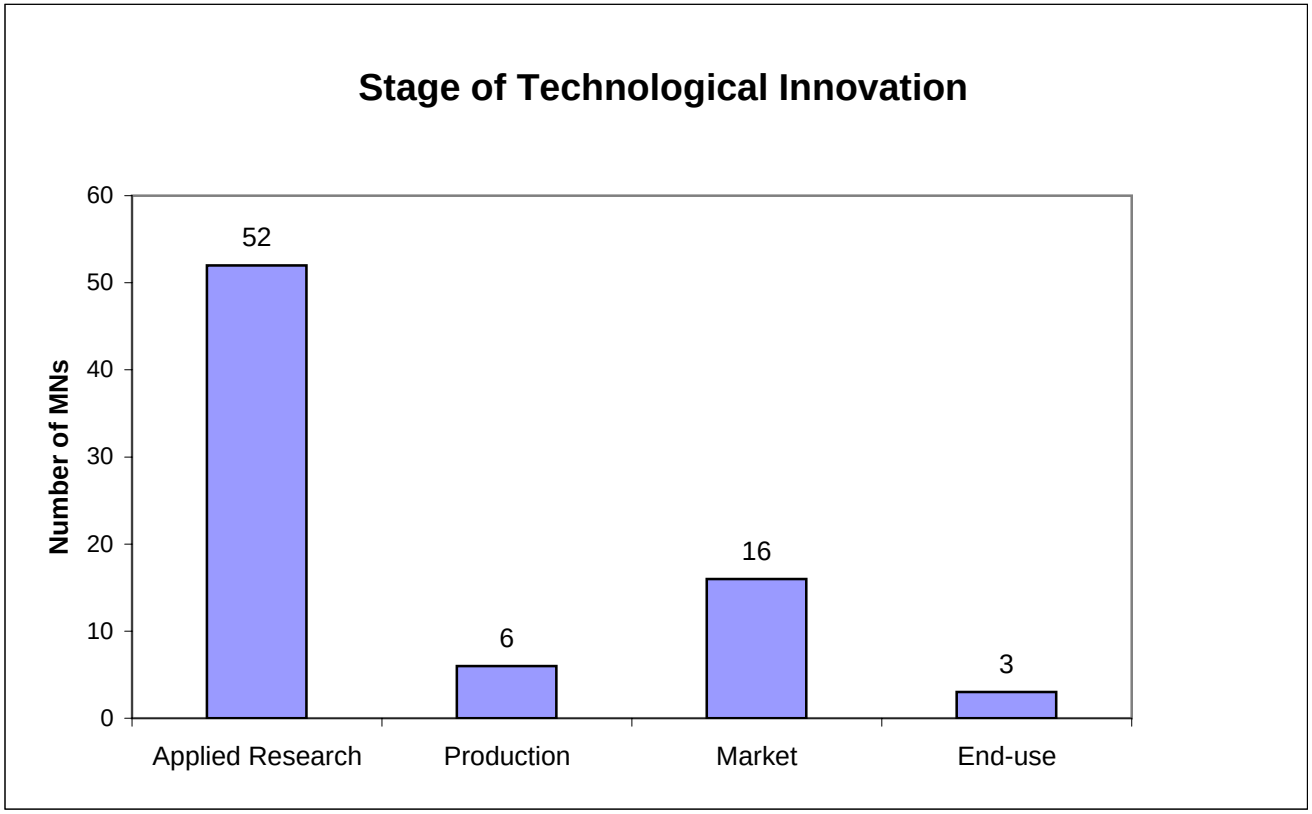

Exhibit 7.8: MN Distribution of Regulation as Driver/Barrier in Healthcare

MN Driver	MN Barrier	No Impact
20	4	53

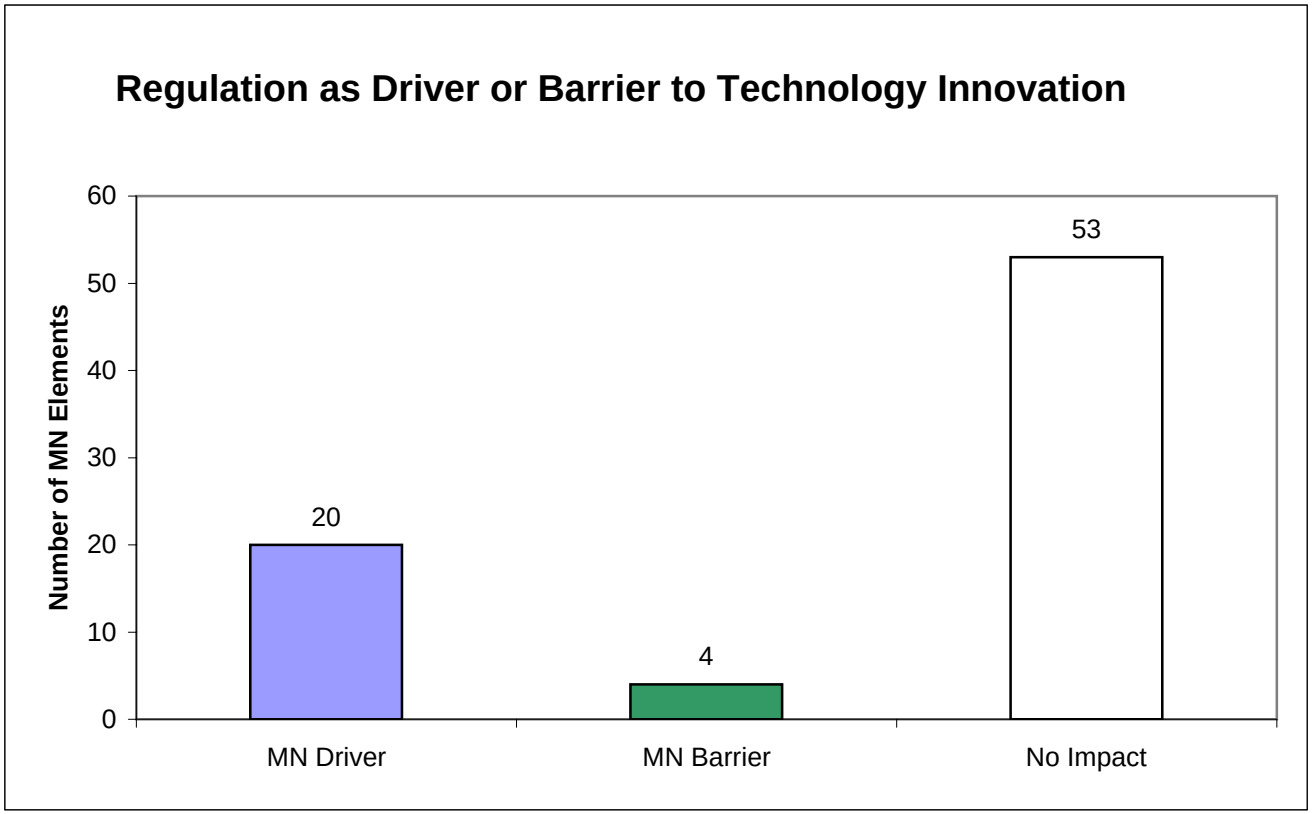

Exhibit 7.9: MN Correlation Matrix for Solution Providers and Measurement Barriers in Healthcare

Solution Providers	Measurement Solution Barriers															
	Acceptability/Compatibility	Accessibility	Accuracy	Data, Data Collection and/or Retrieval	Destructive	Expense	Lack of fundamental knowledge	Multiple Solutions Exist	Not Standardized	Production Readiness	Reliability	Resolution	Small Market Demand	Speed	System-Level Problem	Workforce
Calibration laboratories			1								1					
Commercial calibration service providers																
Component suppliers	1								1							
Contractor R&D labs-for-hire																
Engineering management/consulting firms/A&E firms									1							
Government laboratories and agencies	3		37	13	1	3	20	3	14		13	11		3	2	1
Independent testing/certification laboratories	1		1	1					1							
Industrial R&D laboratories	1		18	4		1	9	3	5	1	6	8		2		
Industry consortium/partnership	3		10	7		4	5		9		6			1	1	
Instrument suppliers	1		13	5		2	6		7	1	5	3			1	
Material suppliers			1	1			1		2		1					
National Measurement Institute	3	1	36	17	1	3	21	2	21	1	20	9		3	3	1
Small business/inventors																
Software developers	1	1	1	2			1									
Standards development organizations (SDOs)	1		4	7	1	1	4		3		3	2		1	1	
Testing laboratories				1					1		1					
Universities		1	18	10		3	13	4	3		7	5		2		1

Exhibit 7.10: MN Correlation Matrix for Measurement Barriers and Measurement Solutions in Healthcare

	Measurement Solutions																								
	Infrastructure								Products													Services			
Measurement Solution Barriers	**Coordination/ facilitation**	**Data Collection/ Retrieval**	**Development for Measurement Technology**	**Fundamental Scientific Knowledge**	**Protocols**	**Research for Measurement Science**	**Standards**	**User Facility**	**Calibration Method**	**Computation Method**	**Measurement Instrument**	**Measurement Method**	**Metrics/ Benchmarks**	**Raw Properties Data**	**Reference Data**	**Software**	**Stability Tests**	**Standard/CRM**	**Test Methods - Production Scale**	**Test Methods - Consumer Products**	**Validated Data**	**Calibration Services**	**Expert Consultation**	**International Recognition**	**3rd Party Verification**
Acceptability/Compatibility		1			2		2		1			1			2	2		1	1	1					
Accessibility		1								1					1										
Accuracy	1	4	18	3	9	11	18	2	7	7	8	14	6	4	6	3	1	9	5	1	2				
Data, Data Collection/and or Retrieval	1	4	7	1	4	2	10	2	2	5	2	7	2	1	5	1		5	1	4	1				1
Destructive							1					1						1							
Expense		1	3			3	3				1	1				1		1	2		1				
Lack of Fundamental Knowledge		2	11	7	2	7	6		2	5	4	7	3	2	4	2	1	6	2	1					
Multiple Solutions Exist			2	1				1	2		1	2	1	1	1										
Not Standardized			4	1	7	2	13		2	2	3	6	3		5	4		5	1	6	1				1
Production Readiness			1			1					1														
Reliability			5	2	5	4	12		2	4	2	9	5	2	4		1	5	2	2	1				1
Resolution	1	2	11	1	2	3	2	1	3	3	3	3	1	1				1							
Small Market Demand																									
Speed			1			1	3		1		2	2			1			1							
System-Level Problem	1		1		2		1					1	2							1					
Workforce			1	1								1													

Exhibit 7.11: MN Correlation Matrix for Measurement Providers and Measurement Solutions in Healthcare

	Measurement Solutions																								
	Infrastructure								Products													Services			
Measurement Solution Providers	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Calibration laboratories							1		1			1													
Commercial calibration service providers																									
Component suppliers					2										1	1			1						
Contractor R&D labs-for-hire																									
Engineering management/consulting firms/A&E firms					1													1		1					
Government laboratories and agencies	2	3	15	6	15	9	19	2	3	8	6	19	8	3	8	5	1	9	5	3	1				
Independent testing/certification laboratories							1					2			1					1					
Industrial R&D laboratories		2	12	2	5	4	6	2	3	2	6	7	5	2	2			1	2	1					
Industry consortium/partnership		1	2	1	3	2	7		2	2	3	5	2		2	4		3	3	3	2				
Instrument suppliers		1	8	3	2	6	5		2	2	3	2		1	3		1	4	2	1	1				
Material suppliers			1			1	1					1						2							
National Measurement Institute	2	2	18	4	13	9	20		8	9	9	20	9	2	10	5	1	12	3	6	1				1
Small business/inventors																									
Software developers		2					1			1					1			1							
Standards development organizations (SDOs)	1	3	1		3		9	1		1		2	2					3	2	2					1
Testing laboratories							1											1							1
Universities		1	11	5	1	8	9	1	4	4	3	12	3	2	6			2	2		1				

Exhibit 7.12: MN Correlation Matrix for Stage of Technological Innovation and Measurement Barriers in Healthcare

Stage of Technological Innovation	Measurement Solution Barriers															
	Acceptability/Compatibility	Accessibility	Accuracy	Data, Data Collection and/or Retrieval	Destructive	Expense	Lack of fundamental knowledge	Multiple Solutions Exist	Not Standardized	Production Readiness	Reliability	Resolution	Small Market Demand	Speed	System-Level Problem	Workforce
Applied Research	1	1	37	16	1	4	25	4	9	1	10	13		3		1
Production	2		1	3					4		2			1	1	
Market	2		10	4		2	1		7		11				2	
End-use			2				1		3							

Exhibit 7.13: MN Correlation Matrix for Stage of Technological Innovation and Measurement Solutions in Healthcare

	Measurement Solutions																								
	Infrastructure								Products													Services			
Stage of Technological Innovation	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Applied Research	1	4	22	7	4	14	16	2	7	9	8	16	4	3	7		1	7	3	2	2				
Production			2		2		2				1	2			1			2	2	3					
Market	1	1			7		9		1	1		7	5	1	3	3		5	2	1					1
End-use					3		1				1		1		1	2									

Exhibit 7.14: MN Correlation Matrix for Solution Providers and Stage of Technological Innovation in Healthcare

Measurement Solution Providers	Stage of Technological Innovation			
	Applied Research	Production	Market	End-use
Calibration laboratories	1			
Commercial calibration service providers				
Component suppliers		1		1
Contractor R&D labs-for-hire				
Engineering management/consulting firms/A&E firms		1		
Government laboratories and agencies	37	4	11	3
Independent testing/certification laboratories	1	1		
Industrial R&D laboratories	20	2	2	1
Industry consortium/partnership	6	2	7	1
Instrument suppliers	13	2	1	
Material suppliers	1		1	
National Measurement Institute	37	4	15	3
Small business/inventors				
Software developers	2			
Standards development organizations (SDOs)	7		4	
Testing laboratories			1	
Universities	25	1	1	

Exhibit 7.15: MN Correlation Matrix for Stage of Technological Innovation and TI as Measurement Technology in Healthcare

Stage of Technological Innovation	TI as Measurement Technology
Applied Research	34
Production	2
Market	8
End-use	3

Exhibit 7.16: MN Correlation Matrix for TI as Measurement Technology and Measurement Barriers in Healthcare

	Measurement Solution Barriers															
Innovation Equivalency	**Acceptability/Compatibility**	**Accessibility**	**Accuracy**	**Data, Data Collection and/or Retrieval**	**Destructive**	**Expense**	**Lack of fundamental knowledge**	**Multiple Solutions Exist**	**Not Standardized**	**Production Readiness**	**Reliability**	**Resolution**	**Small Market Demand**	**Speed**	**System-Level Problem**	**Workforce**
Technology Innovation = Measurement Innovation	3	1	33	18		3	20	3	15	1	12	11			1	

Exhibit 7.17: MN Correlation Matrix for **Solution Providers** and **TI as Measurement Technology** in Healthcare

Measurement Solution Providers	Technology Innovation = Measurement Innovation
Calibration laboratories	1
Commercial calibration service providers	
Component suppliers	1
Contractor R&D labs-for-hire	
Engineering management/consulting firms/A&E firms	
Government laboratories and agencies	32
Independent testing/certification laboratories	1
Industrial R&D laboratories	12
Industry consortium/partnership	10
Instrument suppliers	14
Material suppliers	2
National Measurement Institute	35
Small business/inventors	
Software developers	2
Standards development organizations (SDOs)	6
Testing laboratories	1
Universities	19

Exhibit 7.18: MN Correlation Matrix for **TI as Measurement Technology** and **Measurement Solutions** in Healthcare

	Measurement Solutions																								
	Infrastructure								Products														Services			
Innovation Equivalency	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Technology Innovation = Measurement Innovation		4	16	5	7	11	19	2	6	8	6	10	4	4	7	5	1	11	5	2	2				1

Exhibit 7.19: MN Correlation Matrix for **Regulation as Driver/Barrier** and **Measurement Solutions** in Healthcare

	Measurement Solutions																							
	Infrastructure								Products													Services			
Regulatory Issues	**Coordination/ facilitation**	**Data Collection/ Retrieval**	**Development for Measurement Technology**	**Fundamental Scientific Knowledge**	**Protocols**	**Research for Measurement Science**	**Standards**	**User Facility**	**Calibration Method**	**Computation Method**	**Measurement Instrument**	**Measurement Method**	**Metrics/ Benchmarks**	**Raw Properties Data**	**Reference Data**	**Software**	**Stability Tests**	**Standard/CRM**	**Test Methods - Production Scale**	**Test Methods - Consumer Products**	**Validated Data**	**Calibration Services**	**Expert Consultation**	**International Recognition**	**3rd Party Verification**
Regulation is a Driver		1	4		5	3	9		1	3	2	4	3		2	4		5	6	1	2				
Regulation is a Barrier							4			1	1	2			1			2							1

Exhibit 7.20: MN Correlation Matrix for **Solution Providers** and **Regulation as Driver/Barrier** in Healthcare

Measurement Solution Providers	Regulation is a Driver	Regulation is a Barrier
Calibration laboratories		
Commercial calibration service providers		
Component suppliers		
Contractor R&D labs-for-hire		
Engineering management/consulting firms/A&E firms		
Government laboratories and agencies	17	2
Independent testing/certification laboratories	1	
Industrial R&D laboratories	5	1
Industry consortium/partnership	8	1
Instrument suppliers	2	1
Material suppliers		1
National Measurement Institute	16	4
Small business/inventors		
Software developers		
Standards development organizations (SDOs)	2	1
Testing laboratories		1
Universities	6	

U.S. Measurement System

Measurement Need (MN) Data Book

Chapter 8. Manufacturing (Discrete) and Automotive

Prepared by
Energetics Incorporated
for the
National Institute of Standards and Technology

April 2006

Reference List of MN Distribution Charts and MN Correlation Matrices

Exhibit 8.1: MN Distribution of Measurement Barriers in Manufacturing (Discrete) and Automotive

Acceptibility	Accessibility	Accuracy	Data, Data Collection & Retrieval	Destructive	Expense	Lack of Fundamental Knowledge	Multiple Solutions	Not Standardized	Production Readiness	Reliability	Resolution	Small market demand	Speed	Systems-level	Workforce	Total
3	2	17	18	4	3	3	2	8	0	11	8	0	5	1	0	85

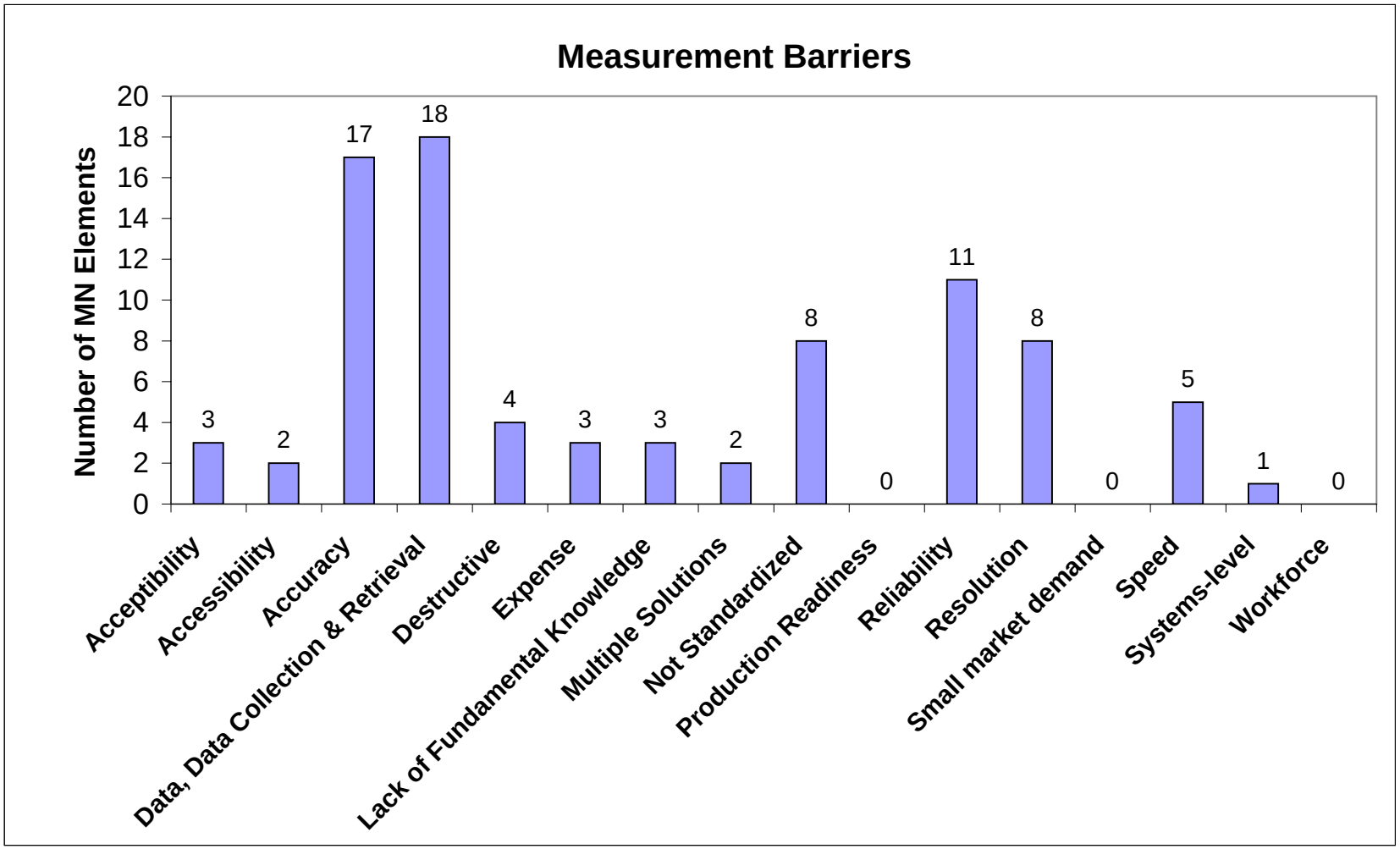

Exhibit 8.2: MN Distribution of Measurement Solution Providers in Manufacturing (Discrete) and Automotive

Calibration Laboratories	Commercial Calibration Service Providers	Component Suppliers	Contractor R&D Labs-for-Hire	Engineering Management/Consulting Firms/A&E Firms	Government Laboratories and Agencies	Independent Testing/Certification Laboratories	Industrial R&D Laboratories	Industry Consortium/ Partnership	Instrument Suppliers	Material Suppliers	National Measurement Institute	Small Business/Inventors	Software Developers	Standards Development Organizations (SDO)	Testing Laboratories	Universities	Total
1	0	3	0	1	11	1	9	8	8	2	24	0	2	4	0	9	83

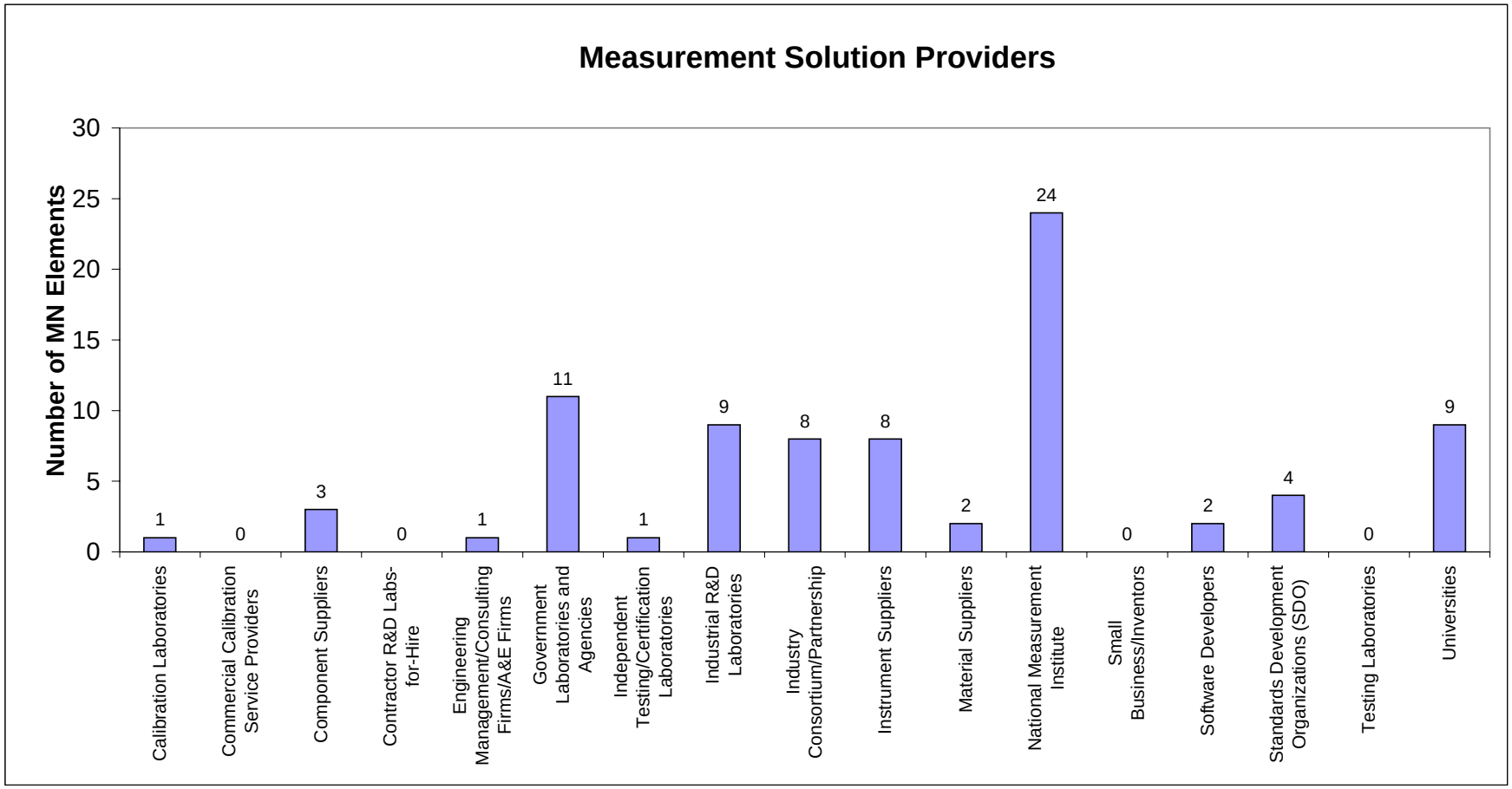

Exhibit 8.3: MN Distribution of Measurement Solutions in Manufacturing (Discrete) and Automotive

Infrastructure								Products													Services				
Coordination/Facilitation	Data Collection/Retrieval	Development - Measurement Technology	Fund-amental Knowledge	Protocols	Research - Measure-ment Science	Standards	User Facility	Calibration	Computational Methods	Measure-ment Instrument	Measure-ment Method	Metrics/Benchmarks	Raw Data	Reference Data	Software	Stability Tests	Standard/certified reference material	Test methods for production-scale measurements	Test methods or test data for consumer products	Validated (hardened) properties data	Calibration	Expert consultation	Intl Recognition	Third Party Verification	Total
4	5	9	2	0	2	10	2	5	8	10	8	2	1	2	1	0	3	6	2	2	0	1	0	4	89

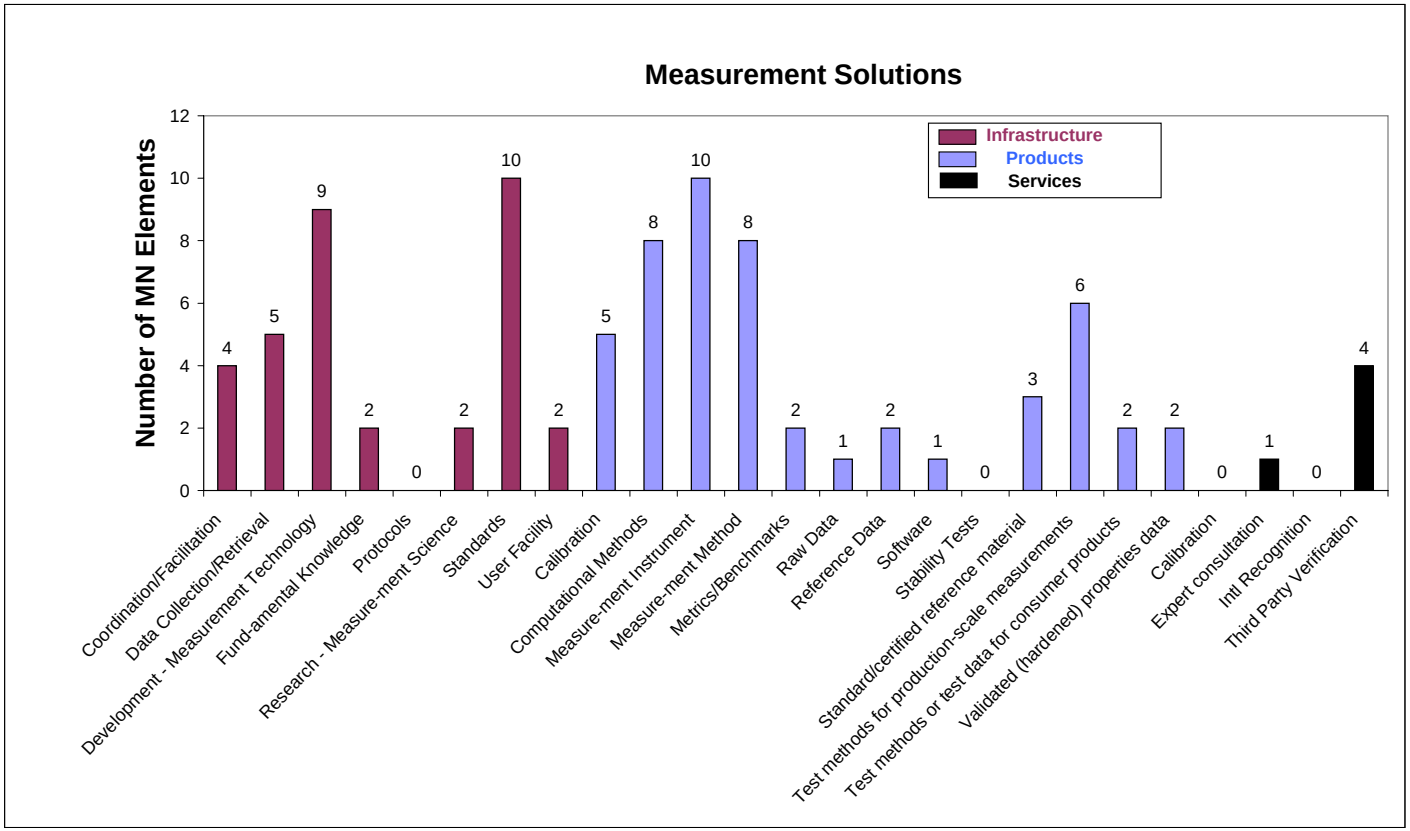

Exhibit 8.4: MN Distribution of Measurands in Manufacturing (Discrete) and Automotive

Classical				Functional									Performance			Structural				
Biological	Chemical	Physical	Physiological	Acoustical	Electronic/ Electrical	Magnetic	Optical	Photonic	Radio frequency	Thermal- Thermochemical	Thermal- Thermodynamic	Thermal- Thermophysical	Computational Performance	Software Performance	System Performance	Kinetic	Mechanical	Molecular	Spatial	Total
0	0	12	1	0	1	0	1	0	1	1	1	2	1	1	2	1	4	0	3	32

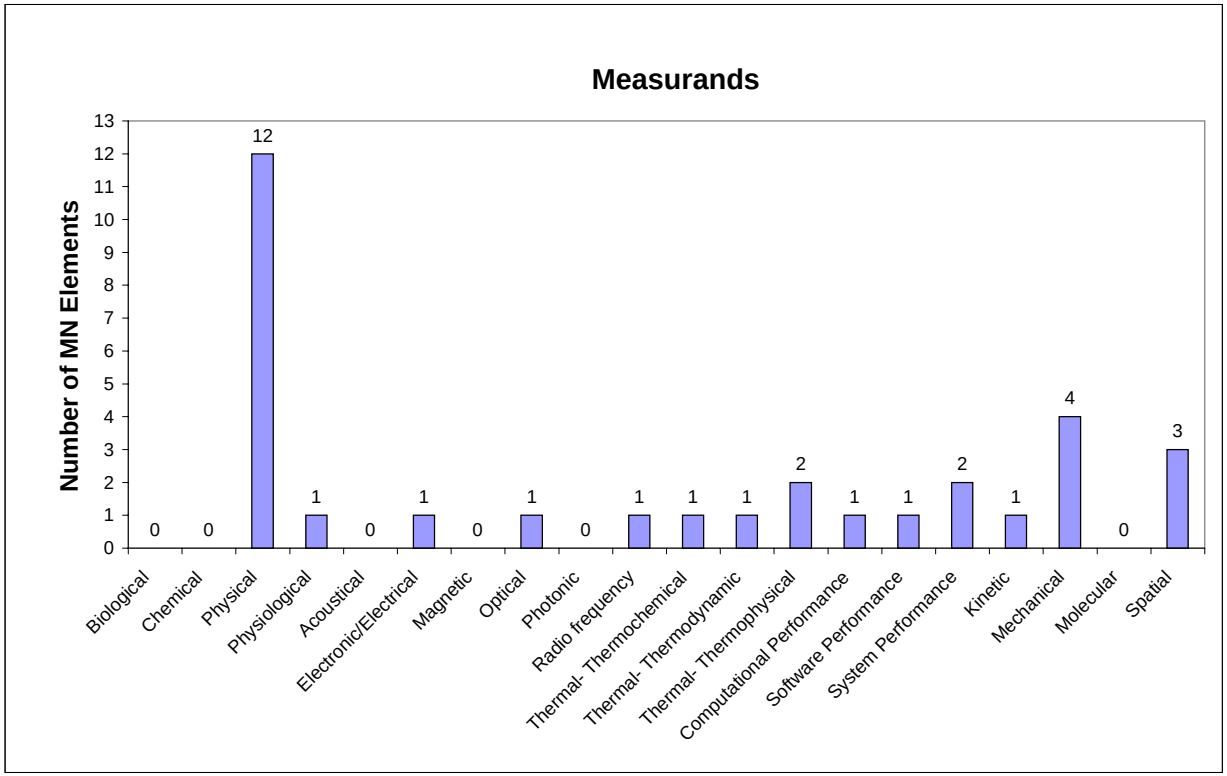

Exhibit 8.5: MN Distribution of Current Public/Private R&D Efforts in Manufacturing (Discrete) and Automotive

Only Private Efforts Exist	Only Public Efforts Exist	Both Public and Private Efforts Exist	No Efforts Exist
3	6	2	21

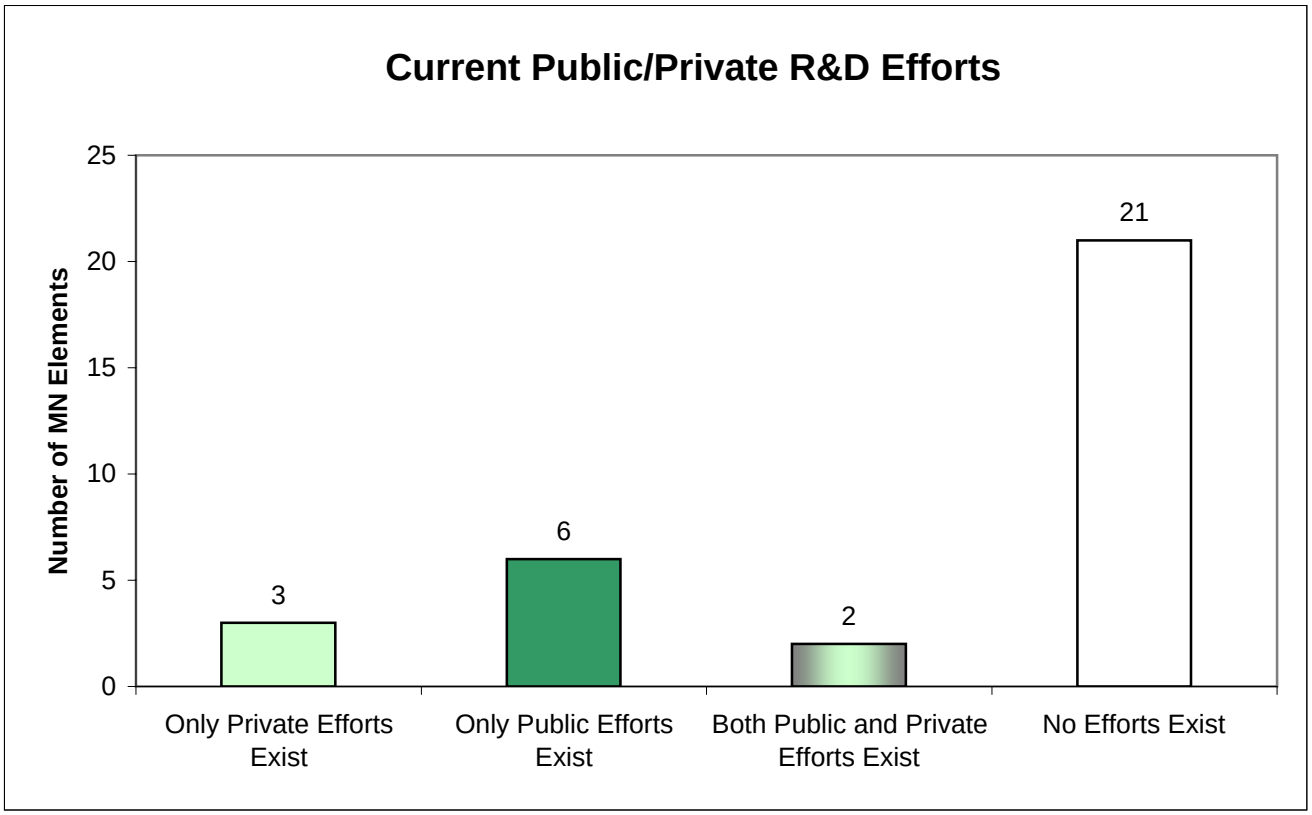

Exhibit 8.6: MN Distribution of TI as Measurement Technology in Manufacturing (Discrete) and Automotive

Technology Innovation is a Measurement Innovation	Technology Innovation is not a Measurement Innovation
20	12

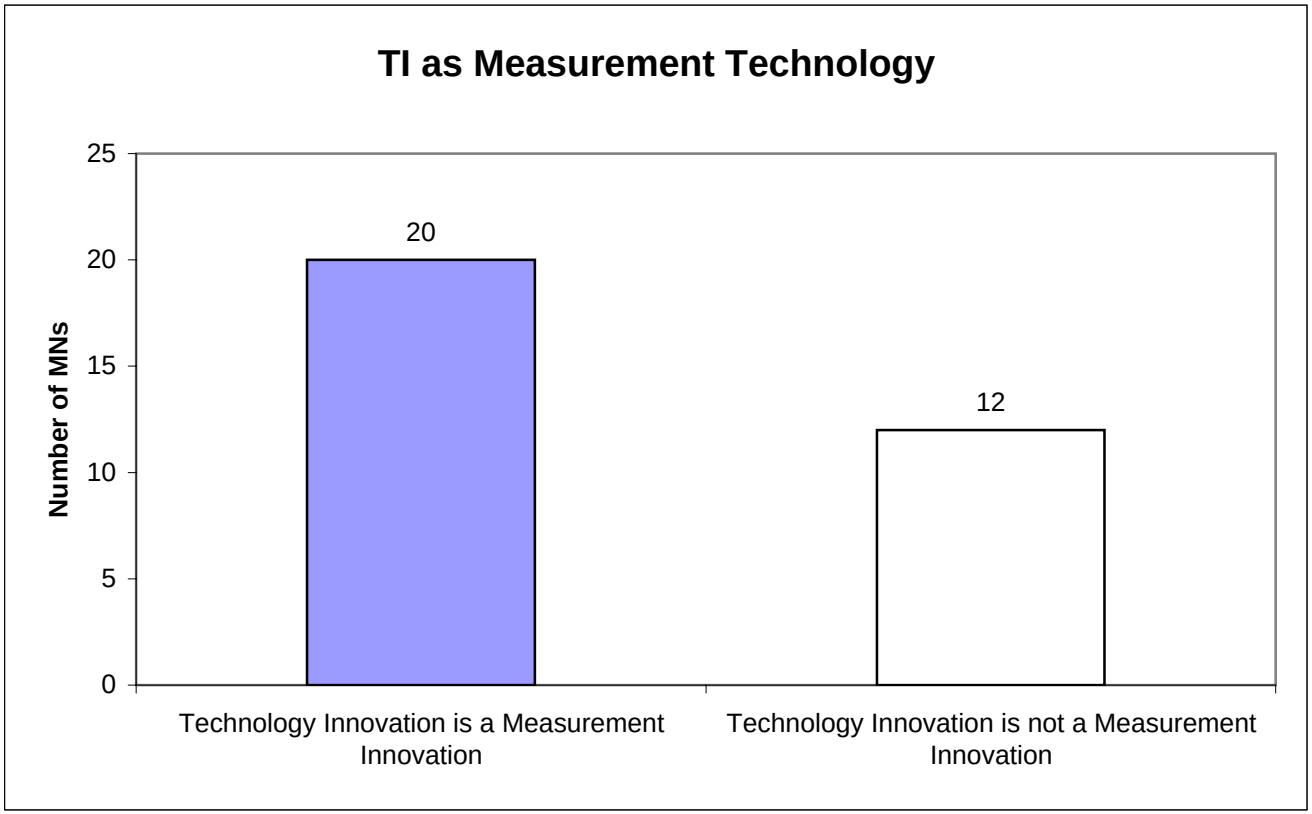

Exhibit 8.7: MN Distribution by Stage of Technological Innovation in Manufacturing (Discrete) and Automotive

Applied Research	Production	Market	End-use	Total
23	7	1	1	32

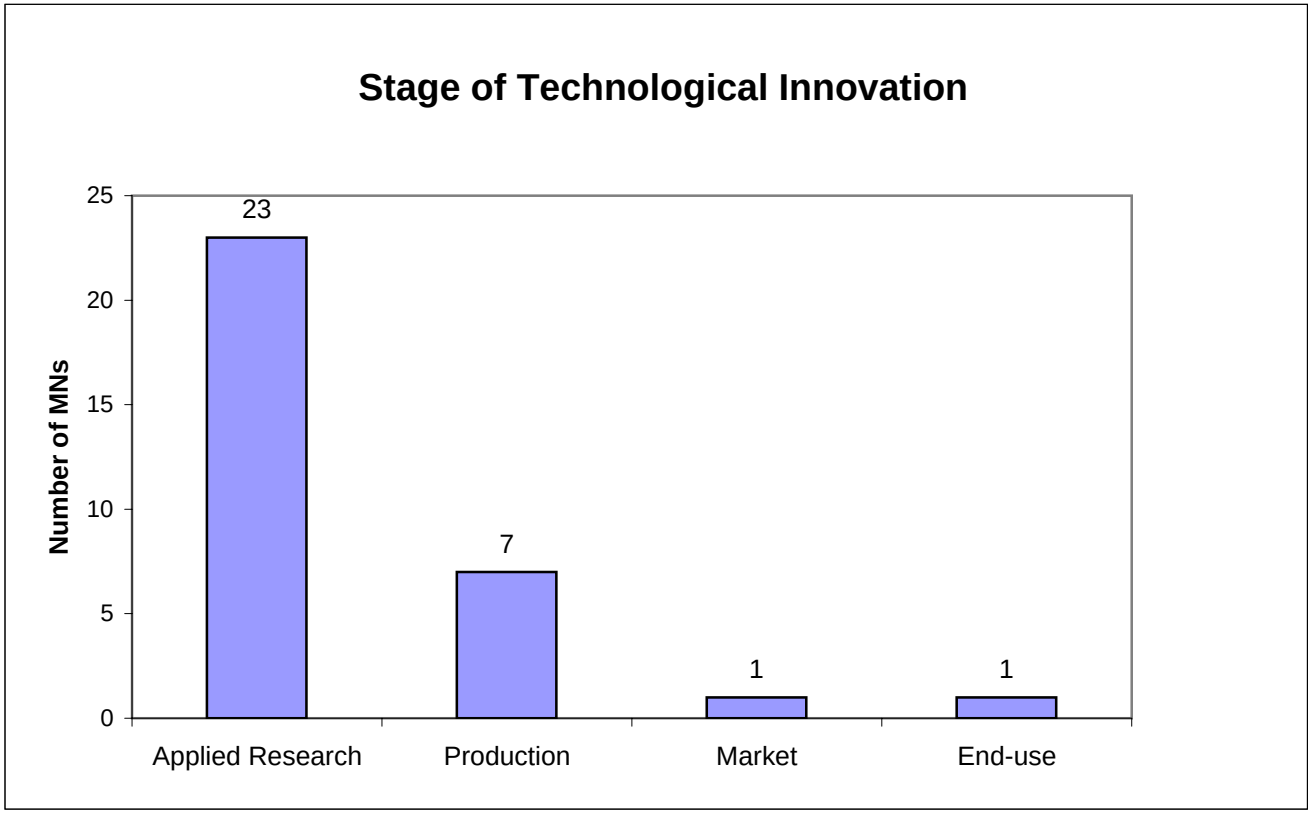

Exhibit 8.8: MN Distribution of Regulation as Driver/Barrier in Manufacturing (Discrete) and Automotive

MN Driver	MN Barrier	No Impact
2	3	27

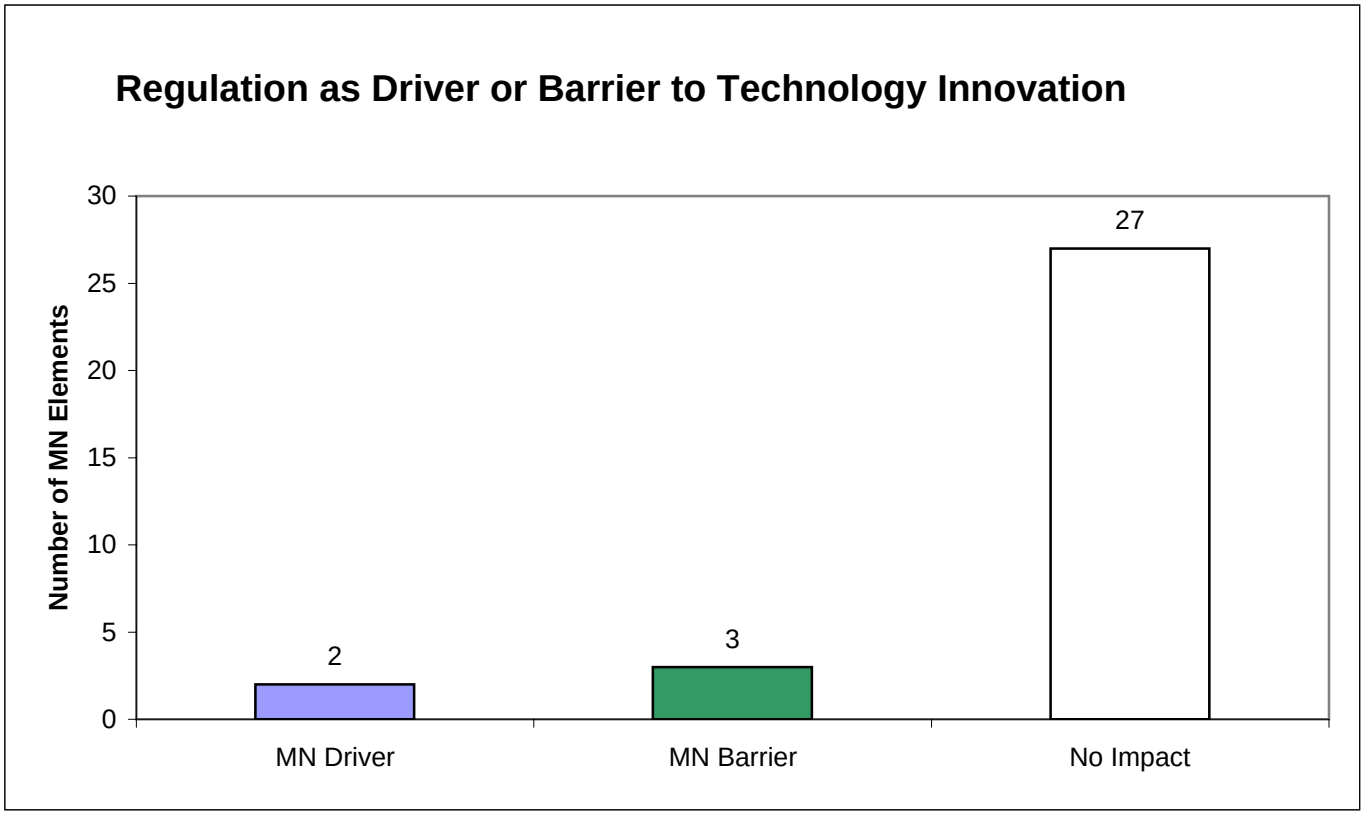

Exhibit 8.9: MN Correlation Matrix for Solution Providers and Measurement Barriers in Manufacturing (Discrete) and Automotive

Solution Providers	Measurement Solution Barriers															
	Acceptability/Compatibility	Accessibility	Accuracy	Data, Data Collection and/or Retrieval	Destructive	Expense	Lack of fundamental knowledge	Multiple Solutions Exist	Not Standardized	Production Readiness	Reliability	Resolution	Small Market Demand	Speed	System-Level Problem	Workforce
Calibration laboratories			1	1					1							
Commercial calibration service providers																
Component suppliers			2	1		1		1	1		3					
Contractor R&D labs-for-hire																
Engineering management/consulting firms/A&E firms				1							1				1	
Government laboratories and agencies	1	1	5	5	2	1	2		1		3	4		4		
Independent testing/certification laboratories				1					1		1					
Industrial R&D laboratories	2		5	4	2		2	1	2		2	4		1		
Industry consortium/partnership		1	5	5	1	1		1	2		3	2				
Instrument suppliers		1	6	4	1	1	1	1	1		3	2		1		
Material suppliers			1	2				1	1							
National Measurement Institute	2	2	14	13	3	2	2	1	6		8	6		4	1	
Small business/inventors																
Software developers	1			1					1		1					
Standards development organizations (SDOs)	1		2	2		1			1		2	1				
Testing laboratories																
Universities	1	1	4	6	1	1	1		1		2	2		3		

Exhibit 8.10: MN Correlation Matrix for Measurement Barriers and Measurement Solutions in Manufacturing (Discrete) and Automotive

	Measurement Solutions																								
	Infrastructure								Products													Services			
Measurement Solution Barriers	**Coordination/ facilitation**	**Data Collection/ Retrieval**	**Development for Measurement Technology**	**Fundamental Scientific Knowledge**	**Protocols**	**Research for Measurement Science**	**Standards**	**User Facility**	**Calibration Method**	**Computation Method**	**Measurement Instrument**	**Measurement Method**	**Metrics/ Benchmarks**	**Raw Properties Data**	**Reference Data**	**Software**	**Stability Tests**	**Standard/CRM**	**Test Methods - Production Scale**	**Test Methods - Consumer Products**	**Validated Data**	**Calibration Services**	**Expert Consultation**	**International Recognition**	**3rd Party Verification**
Acceptability/Compatibility	1						2				1								1	1					
Accessibility			1					1	2			1							1						
Accuracy		2	7			2	5	2	5	2	5	4	1	1	1			3	4	1			1		2
Data, Data Collection/and or Retrieval	3	5	2	1		1	7	1	1	6	5	3	2	1	2	1			4	2	2				3
Destructive	1		1						1	2	2	3						1			1				
Expense		1							2	1	2							1							1
Lack of Fundamental Knowledge	1			1							3	2								1					
Multiple Solutions Exist			2			2	1				1														
Not Standardized	1	1					5	1		2	1		2	1	1			1	3		1				1
Production Readiness																									
Reliability	1	2	4	1		1	2		3	2	2	1			1	1		2	2	1	1				4
Resolution			3	1			2	1	1	1	4	6						1	1				1		
Small Market Demand																									
Speed	1	1	3	1						3	3	2													
System-Level Problem	1	1														1									
Workforce																									

Exhibit 8.11: MN Correlation Matrix for Measurement Providers and Measurement Solutions in Manufacturing (Discrete) and Automotive

	Measurement Solutions																									
	Infrastructure								Products														Services			
Measurement Solution Providers	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Calibration laboratories							1							1					1						
Commercial calibration service providers																									
Component suppliers			1			1	1		1		2								1						1
Contractor R&D labs-for-hire																									
Engineering management/consulting firms/A&E firms	1	1														1									
Government laboratories and agencies	1	1	3	1			2	1	2	3	6	5	1							2					1
Independent testing/certification laboratories							1												1						1
Industrial R&D laboratories	1	1	3			1	2			1	5	3						1	2	2			1		1
Industry consortium/partnership		1	1			1	4	1	2	3	1	3							2		2				1
Instrument suppliers	1	1	4	1		1	3		2	2	1	2		1				2	2						1
Material suppliers			1			1	2			1			1												
National Measurement Institute	4	5	8	2		1	5	2	4	6	7	6	1	1	1	1		3	5	1	2		1		2
Small business/inventors																									
Software developers	1						2								1										1
Standards development organizations (SDOs)							3			1		1			1			1	1						2
Testing laboratories																									
Universities		1	3				3		2	4	5	2	1		1				2	1					1

Exhibit 8.12: MN Correlation Matrix for Stage of Technological Innovation and Measurement Barriers in Manufacturing (Discrete) and Automotive

Stage of Technological Innovation	Measurement Solution Barriers															
	Acceptability/Compatibility	Accessibility	Accuracy	Data, Data Collection and/or Retrieval	Destructive	Expense	Lack of fundamental knowledge	Multiple Solutions Exist	Not Standardized	Production Readiness	Reliability	Resolution	Small Market Demand	Speed	System-Level Problem	Workforce
Applied Research	1	2	14	12	3	2	3	1	5		8	7		4		
Production	1		3	5	1	1		1	1		3	1		1	1	
Market				1					1							
End-use	1								1							

Exhibit 8.13: MN Correlation Matrix for Stage of Technological Innovation and Measurement Solutions in Manufacturing (Discrete) and Automotive

	Measurement Solutions																								
	Infrastructure								Products													Services			
Stage of Technological Innovation	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Applied Research	1	3	8	2		1	5	2	5	4	10	6	1	1	2			2	5	2	1		1		3
Production	2	2	1			1	3			3		2				1		1	1		1				1
Market							1			1			1												
End-use	1						1																		

Exhibit 8.14: MN Correlation Matrix for Solution Providers and Stage of Technological Innovation in Manufacturing (Discrete) and Automotive

Measurement Solution Providers	Stage of Technological Innovation			
	Applied Research	Production	Market	End-use
Calibration laboratories	1			
Commercial calibration service providers				
Component suppliers	3			
Contractor R&D labs-for-hire				
Engineering management/consulting firms/A&E firms		1		
Government laboratories and agencies	9	1	1	
Independent testing/certification laboratories	1			
Industrial R&D laboratories	8	1		
Industry consortium/partnership	5	3		
Instrument suppliers	5	3		
Material suppliers		1	1	
National Measurement Institute	18	5		1
Small business/inventors				
Software developers	1			1
Standards development organizations (SDOs)	1	3		
Testing laboratories				
Universities	8		1	

Exhibit 8.15: MN Correlation Matrix for Stage of Technological Innovation and TI as Measurement Technology in Manufacturing (Discrete) and Automotive

Stage of Technological Innovation	TI as Measurement Technology
Applied Research	15
Production	4
Market	
End-use	1

Exhibit 8.16: MN Correlation Matrix for TI as Measurement Technology and Measurement Barriers in Manufacturing (Discrete) and Automotive

Innovation Equivalency	Measurement Solution Barriers															
	Acceptability/Compatibility	Accessibility	Accuracy	Data, Data Collection and/or Retrieval	Destructive	Expense	Lack of fundamental knowledge	Multiple Solutions Exist	Not Standardized	Production Readiness	Reliability	Resolution	Small Market Demand	Speed	System-Level Problem	Workforce
Technology Innovation = Measurement Innovation	2	2	13	10	1	2	1	1	5		6	6		3	1	

Exhibit 8.17: MN Correlation Matrix for Solution Providers and TI as Measurement Technology in Manufacturing (Discrete) and Automotive

Measurement Solution Providers	Technology Innovation = Measurement Innovation
Calibration laboratories	1
Commercial calibration service providers	
Component suppliers	2
Contractor R&D labs-for-hire	
Engineering management/consulting firms/A&E firms	1
Government laboratories and agencies	6
Independent testing/certification laboratories	
Industrial R&D laboratories	5
Industry consortium/partnership	4
Instrument suppliers	6
Material suppliers	
National Measurement Institute	18
Small business/inventors	
Software developers	1
Standards development organizations (SDOs)	2
Testing laboratories	
Universities	4

Exhibit 8.18: MN Correlation Matrix for TI as Measurement Technology and Measurement Solutions in Manufacturing (Discrete) and Automotive

	Measurement Solutions																								
	Infrastructure								Products														Services			
Innovation Equivalency	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Technology Innovation = Measurement Innovation	3	5	7	1		1	5	2	5	3	6	5	1	1	1	1		1	4	1	1		1		1

Exhibit 8.19: MN Correlation Matrix for Regulation as Driver/Barrier and Measurement Solutions in Manufacturing (Discrete) and Automotive

	Measurement Solutions																							
	Infrastructure								Products													Services			
Regulatory Issues	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Regulation is a Driver	1	1					1									1			1					
Regulation is a Barrier		1					2			1			1	1					1	1					1

Exhibit 8.20: MN Correlation Matrix for Solution Providers and Regulation as Driver/Barrier in Manufacturing (Discrete) and Automotive

Measurement Solution Providers	Regulation is a Driver	Regulation is a Barrier
Calibration laboratories		1
Commercial calibration service providers		
Component suppliers		
Contractor R&D labs-for-hire		
Engineering management/consulting firms/A&E firms	1	
Government laboratories and agencies		2
Independent testing/certification laboratories		
Industrial R&D laboratories	1	1
Industry consortium/partnership		
Instrument suppliers		1
Material suppliers		1
National Measurement Institute	2	2
Small business/inventors		
Software developers		
Standards development organizations (SDOs)	1	
Testing laboratories		
Universities		1

U.S. Measurement System

Measurement Need (MN) Data Book

Chapter 9. Materials

(includes Ceramics, Metals, and Polymers)

Prepared by
Energetics Incorporated
for the
National Institute of Standards and Technology

April 2006

Reference List of MN Distribution Charts and MN Correlation Matrices

Exhibit 9.1: MN Distribution of Measurement Barriers in Materials

Acceptibility	Accessibility	Accuracy	Data, Data Collection & Retrieval	Destructive	Expense	Lack of Fundamental Knowledge	Multiple Solutions	Not Standardized	Production Readiness	Reliability	Resolution	Small market demand	Speed	Systems-level	Workforce	Total
3	3	21	17	2	2	12	3	6	3	5	11	0	2	0	1	91

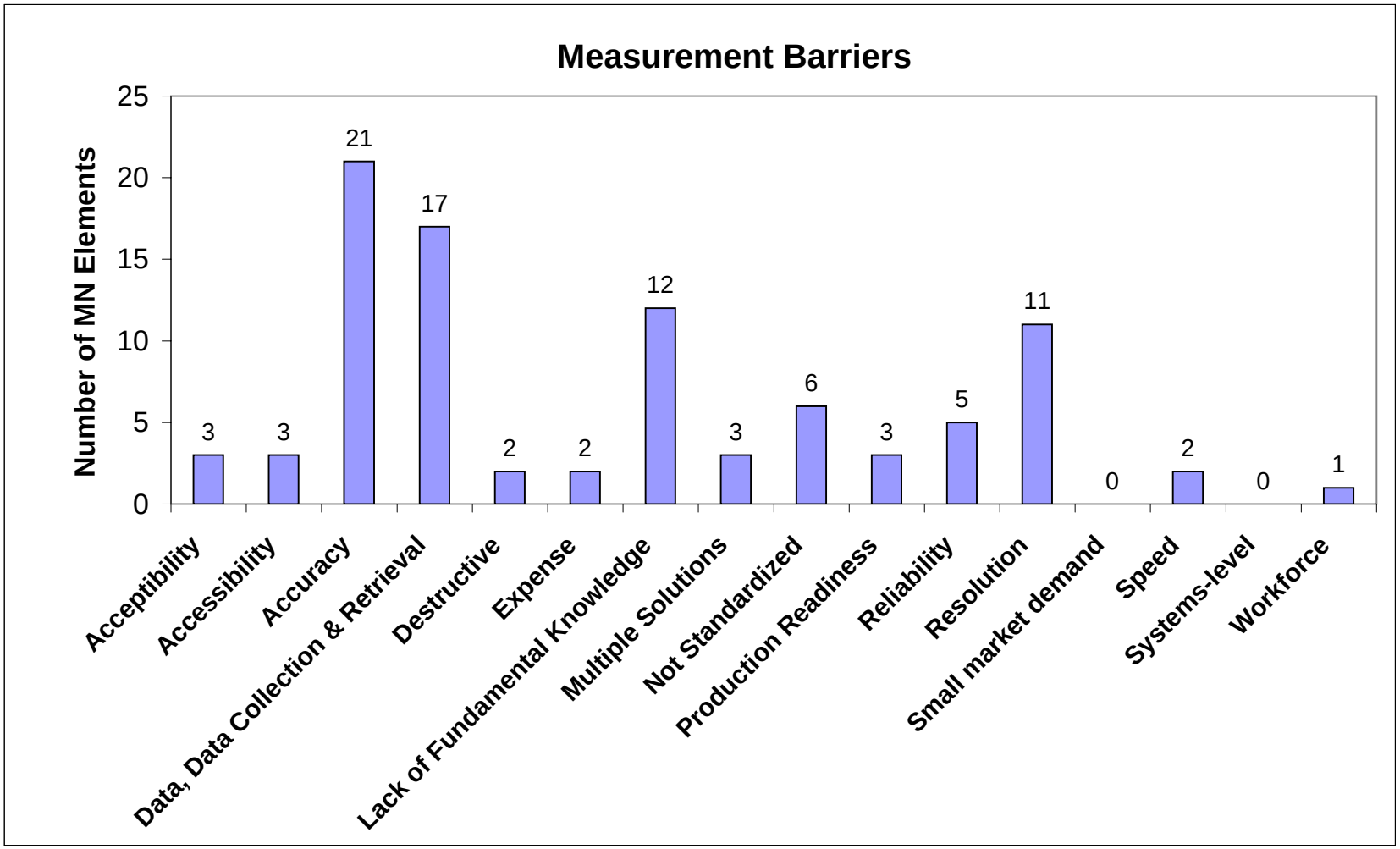

Exhibit 9.2: MN Distribution of Measurement Solution Providers in Materials

Calibration Laboratories	Commercial Calibration Service Providers	Component Suppliers	Contractor R&D Labs-for-Hire	Engineering Management/Consulting Firms/A&E Firms	Government Laboratories and Agencies	Independent Testing/Certification Laboratories	Industrial R&D Laboratories	Industry Consortium/ Partnership	Instrument Suppliers	Material Suppliers	National Measurement Institute	Small Business/Inventors	Software Developers	Standards Development Organizations (SDO)	Testing Laboratories	Universities	Total
0	0	1	0	0	27	2	8	9	9	6	25	0	0	10	0	16	113

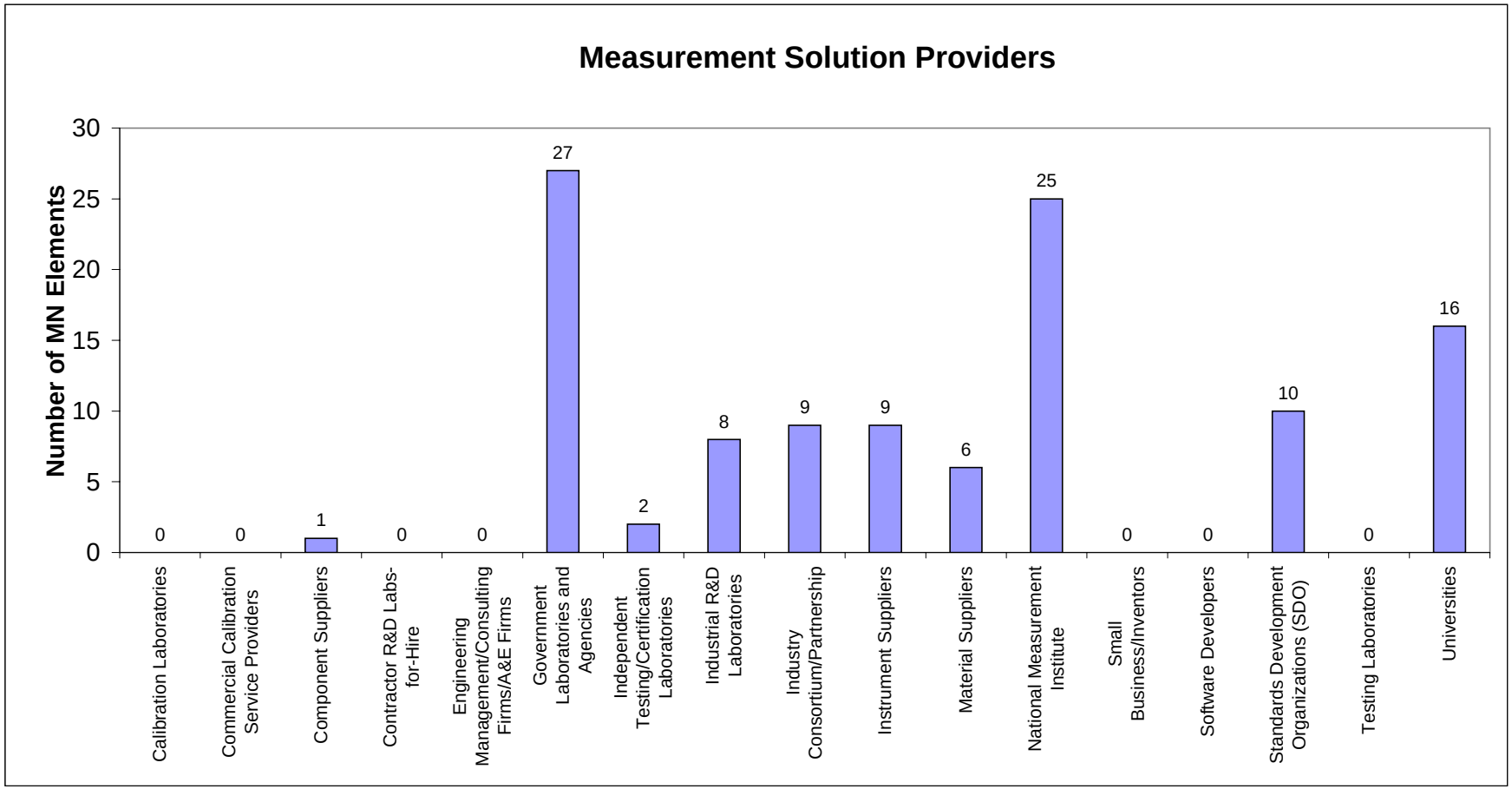

Exhibit 9.3: MN Distribution of Measurement Solutions in Materials

Infrastructure								Products													Services				
Coordination/Facilitation	Data Collection/Retrieval	Development - Measurement Technology	Fund-amental Knowledge	Protocols	Research - Measure-ment Science	Standards	User Facility	Calibration	Computational Methods	Measure-ment Instrument	Measure-ment Method	Metrics/Benchmarks	Raw Data	Reference Data	Software	Stability Tests	Standard/certified reference material	Test methods for production-scale measurements	Test methods or test data for consumer products	Validated (hardened) properties data	Calibration	Expert consultation	Intl Recognition	Third Party Verification	Total
2	1	16	6	4	8	10	3	1	9	2	16	2	5	3	0	0	4	2	0	1	0	0	2	2	99

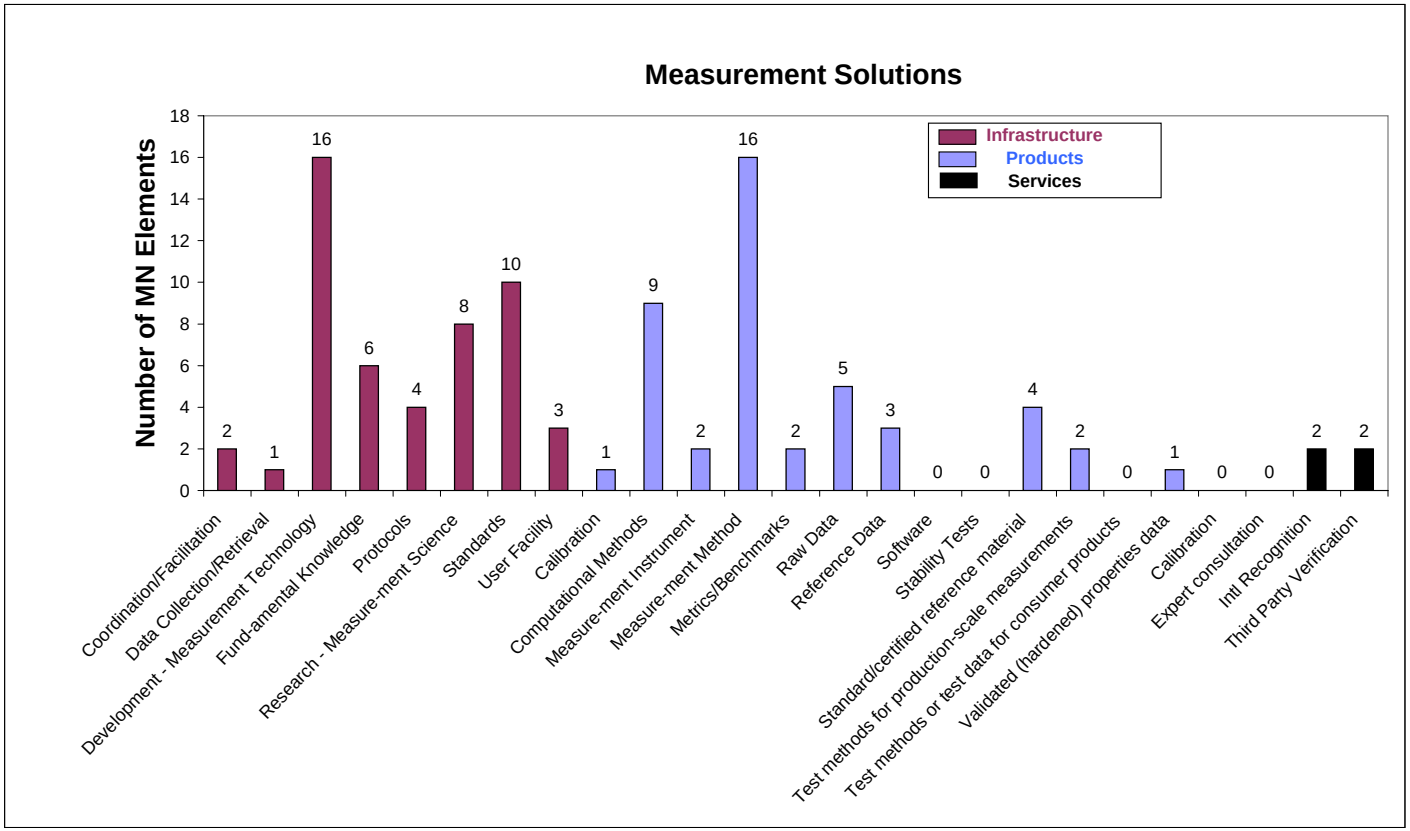

Exhibit 9.4: MN Distribution of Measurands in Materials

Classical				Functional									Performance			Structural				
Biological	Chemical	Physical	Physiological	Acoustical	Electronic/ Electrical	Magnetic	Optical	Photonic	Radio frequency	Thermal- Thermochemical	Thermal- Thermodynamic	Thermal- Thermophysical	Computational Performance	Software Performance	System Performance	Kinetic	Mechanical	Molecular	Spatial	Total
0	8	8	1	0	4	3	0	1	1	0	2	2	0	0	1	0	5	4	0	40

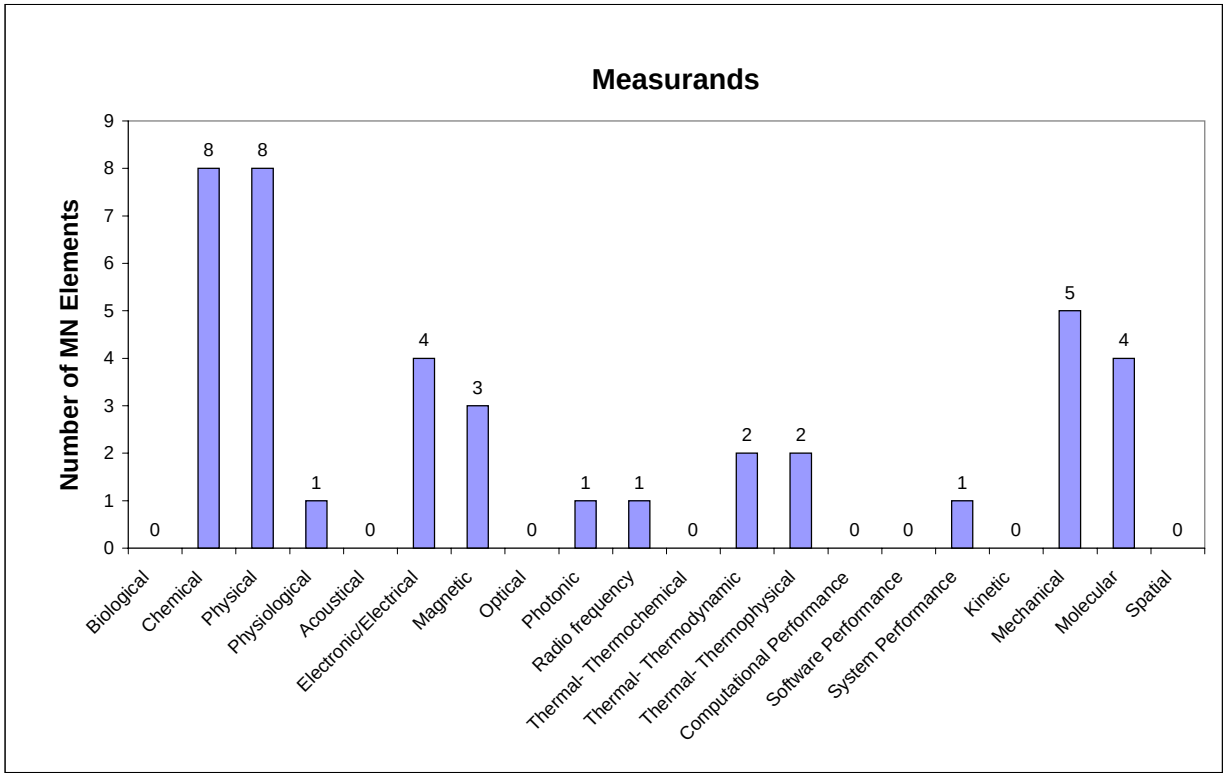

Exhibit 9.5: MN Distribution of Current Public/Private R&D Efforts in Materials

Only Private Efforts Exist	Only Public Efforts Exist	Both Public and Private Efforts Exist	No Efforts Exist
6	5	14	15

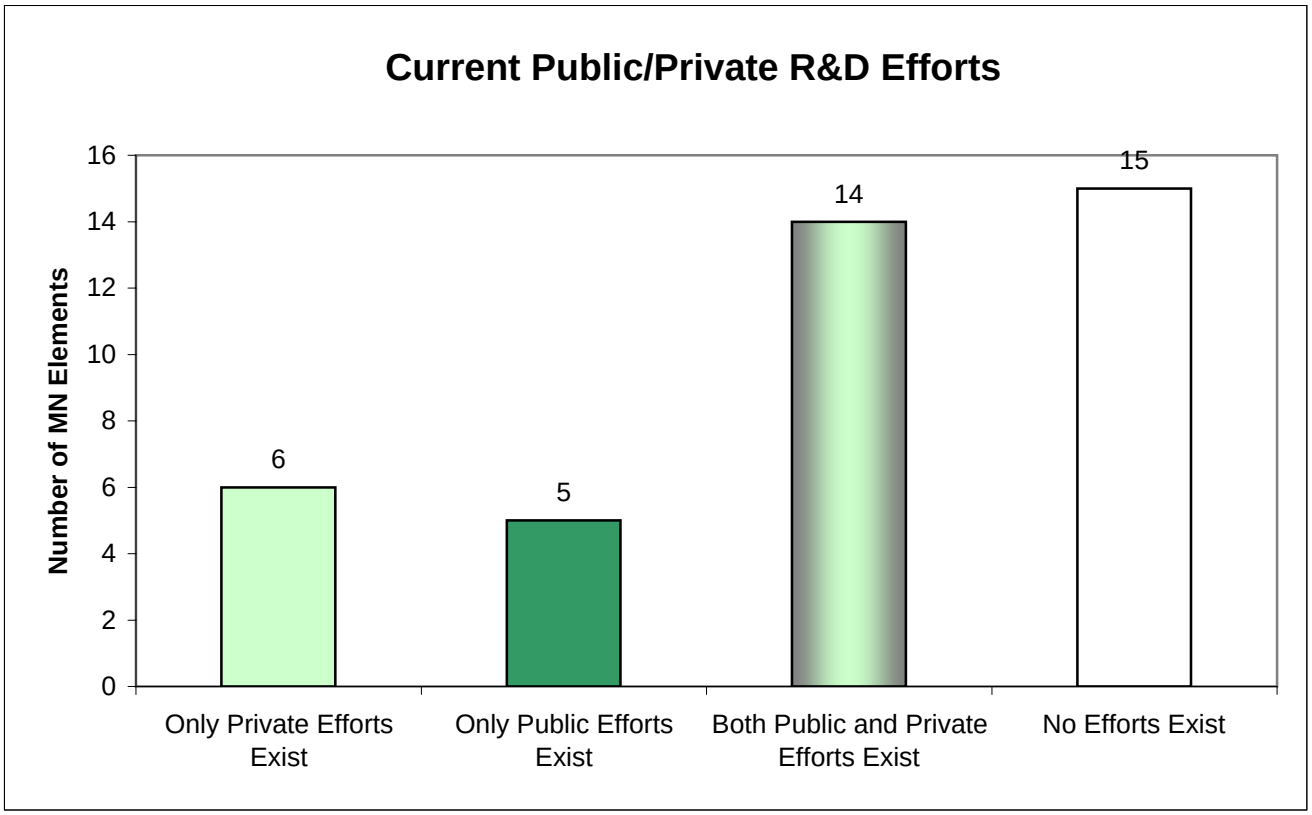

Exhibit 9.6: MN Distribution of TI as Measurement Technology in Materials

Technology Innovation is a Measurement Innovation	Technology Innovation is not a Measurement Innovation
10	30

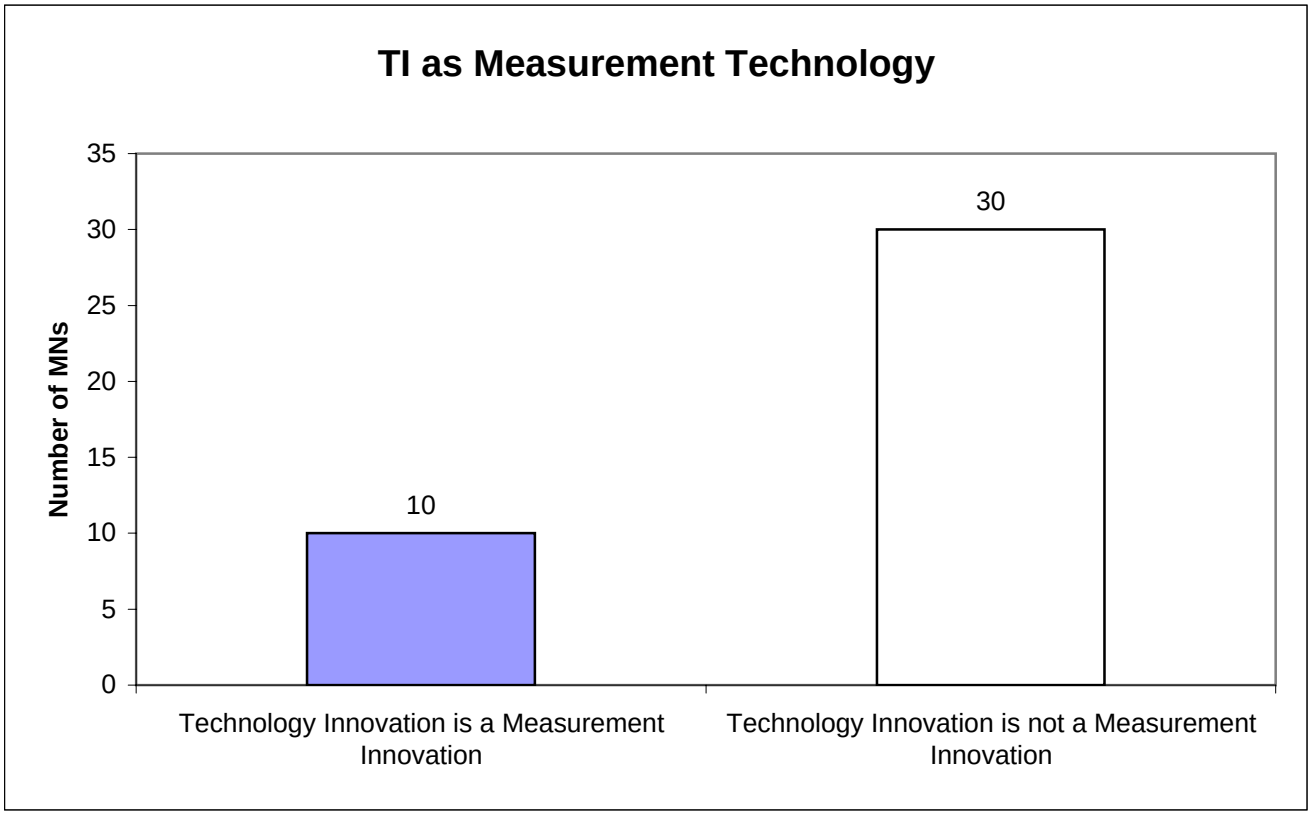

Exhibit 9.7: MN Distribution by Stage of Technological Innovation in Materials

Applied Research	Production	Market	End-use	Total
28	9	3	0	40

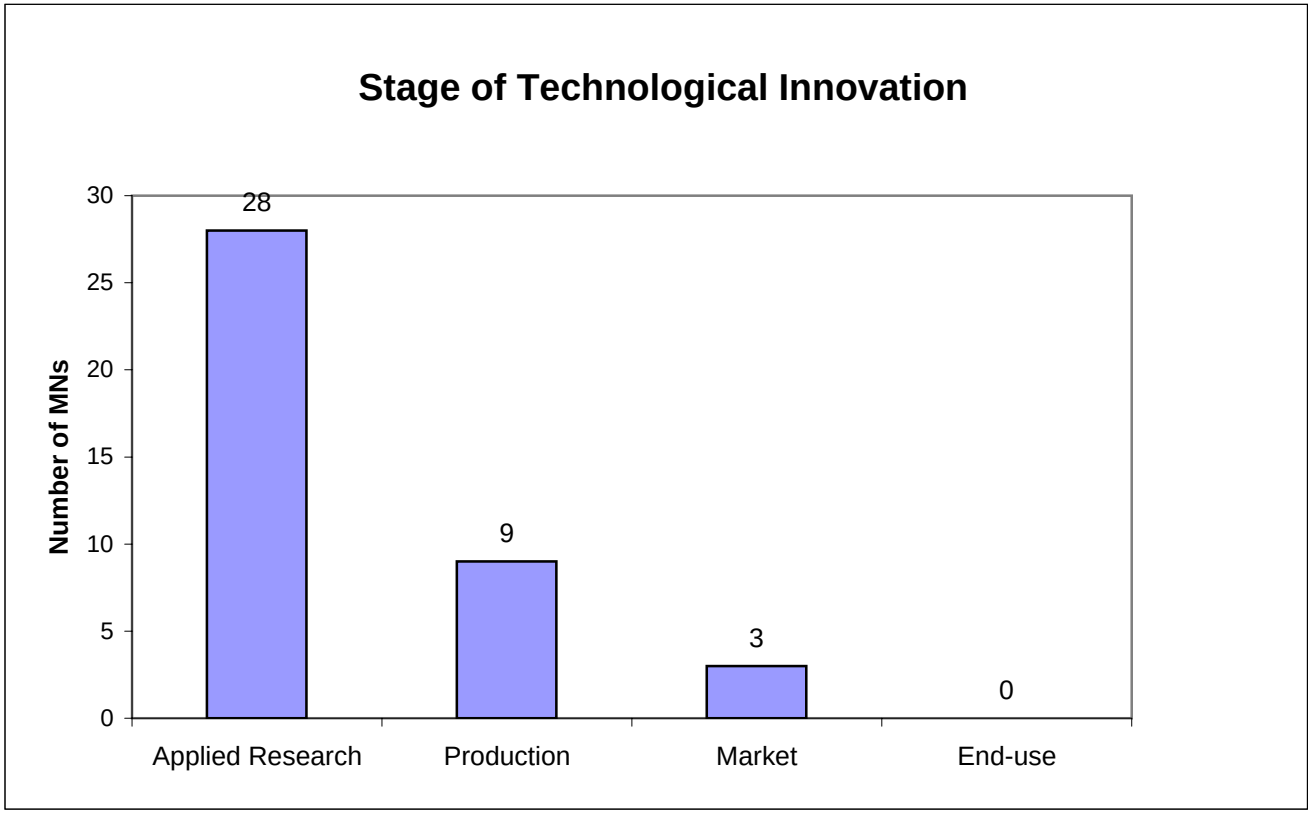

Exhibit 9.8: MN Distribution of Regulation as Driver/Barrier in Materials

MN Driver	MN Barrier	No Impact
4	1	35

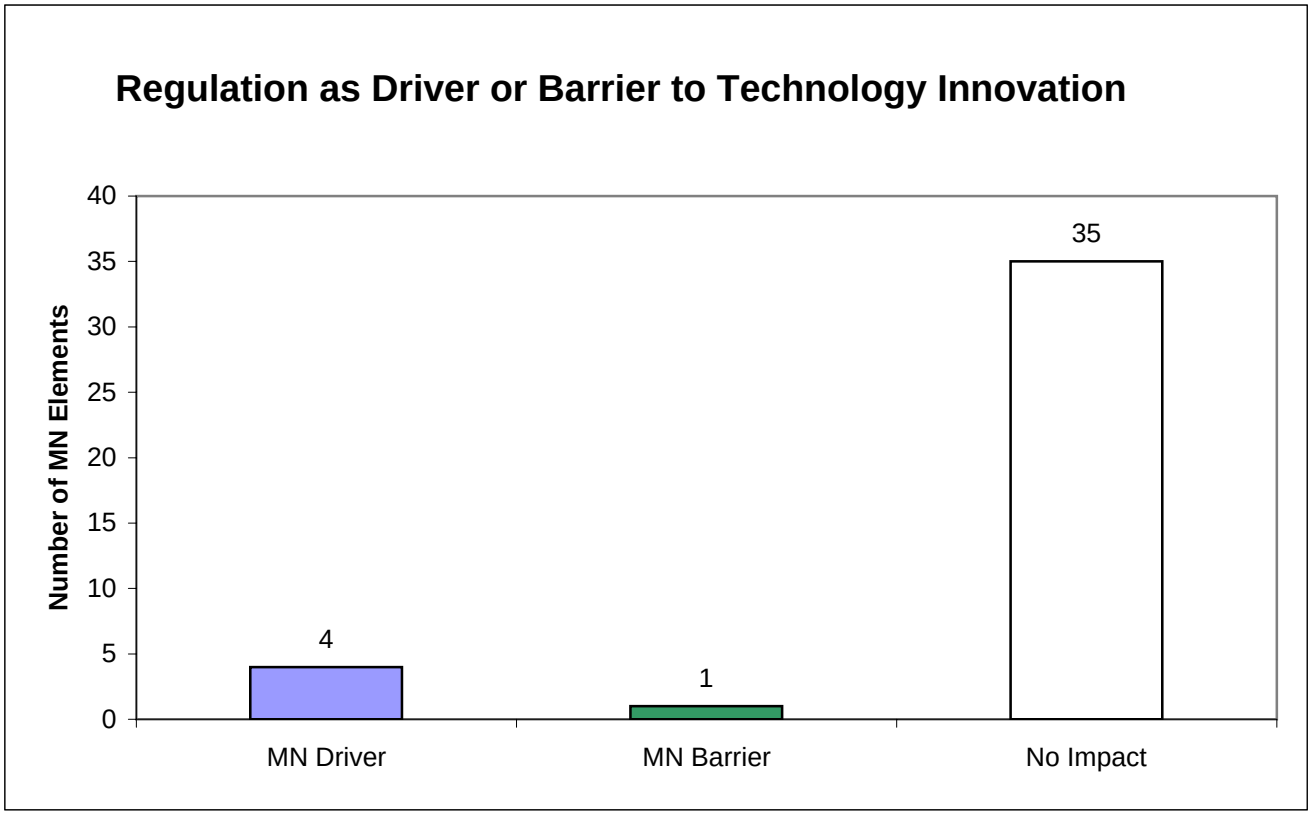

Exhibit 9.9: MN Correlation Matrix for Solution Providers and Measurement Barriers in Materials

Solution Providers	Measurement Solution Barriers															
	Acceptability/Compatibility	Accessibility	Accuracy	Data, Data Collection and/or Retrieval	Destructive	Expense	Lack of fundamental knowledge	Multiple Solutions Exist	Not Standardized	Production Readiness	Reliability	Resolution	Small Market Demand	Speed	System-Level Problem	Workforce
Calibration laboratories																
Commercial calibration service providers																
Component suppliers								1	1							
Contractor R&D labs-for-hire																
Engineering management/consulting firms/A&E firms																
Government laboratories and agencies	1	2	14	9	1	1	11		2	3	2	10		1		1
Independent testing/certification laboratories	1		1						2							
Industrial R&D laboratories	1		5	2	1		4		1		1	3				
Industry consortium/partnership		2	6	4	1	1	1	1		1	1	3		1		
Instrument suppliers			6	3			4	1	1	1		2				
Material suppliers	2	1	3	5			1	2	1			1		1		
National Measurement Institute	1	2	13	11	2	2	6	1	4	2	5	8		2		1
Small business/inventors																
Software developers																
Standards development organizations (SDOs)	2	1	4	3			1	2	5	1	1	1				
Testing laboratories																
Universities	1	1	7	11		1	6	1			3	4		1		1

Exhibit 9.10: MN Correlation Matrix for Measurement Barriers and Measurement Solutions in Materials

	Measurement Solutions																							
	Infrastructure								Products													Services			
Measurement Solution Barriers	**Coordination/ facilitation**	**Data Collection/ Retrieval**	**Development for Measurement Technology**	**Fundamental Scientific Knowledge**	**Protocols**	**Research for Measurement Science**	**Standards**	**User Facility**	**Calibration Method**	**Computation Method**	**Measurement Instrument**	**Measurement Method**	**Metrics/ Benchmarks**	**Raw Properties Data**	**Reference Data**	**Software**	**Stability Tests**	**Standard/CRM**	**Test Methods - Production Scale**	**Test Methods - Consumer Products**	**Validated Data**	**Calibration Services**	**Expert Consultation**	**International Recognition**	**3rd Party Verification**
Acceptability/Compatibility		1	1		1		1							1				1	1					2	
Accessibility	1						1		1		1	3						1							1
Accuracy	2		11	1	2	4	6	1	1	2	1	8	2	3	2			2	1						1
Data, Data Collection/and or Retrieval	1	1	5		3	4	5	2	1	7	1	6	1	4	1			2	1		1			1	1
Destructive				1		1				1		2									1				
Expense			1			1	1				1	1													
Lack of Fundamental Knowledge			5	6	3	4	1	1		4		3	1	1				1							
Multiple Solutions Exist		1	1			1	3					1												1	1
Not Standardized	1				1		2			1		4		1				3	1					1	1
Production Readiness			2									1			1										
Reliability			2			2				3		2		1				1			1				
Resolution	1		7			1	3	2		3	1	5	2	2	1										
Small Market Demand																									
Speed							1	1		1	1	2													
System-Level Problem																									
Workforce			1	1								1													

Exhibit 9.11: MN Correlation Matrix for Measurement Providers and Measurement Solutions in Materials

	Measurement Solutions																									
	Infrastructure								Products														Services			
Measurement Solution Providers	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Calibration laboratories																										
Commercial calibration service providers																										
Component suppliers							1					1														1
Contractor R&D labs-for-hire																										
Engineering management/consulting firms/A&E firms																										
Government laboratories and agencies	2		13	6	3	5	5	2		4	2	11	2	4	3			1								
Independent testing/certification laboratories							1					1		1				1	1						1	
Industrial R&D laboratories			5	2	1	3	1			2		2	1	2	1			1								
Industry consortium/partnership			3			1	5		1	3	1	5			1				1		1					1
Instrument suppliers			7	3	2	3	2	1		1	1							1								
Material suppliers	1	1	2		1	2	2	1		2		2		2				1							1	
National Measurement Institute	1		9	3	1	4	4	3	1	7	2	13	2	2	2			3	2		1				1	2
Small business/inventors																										
Software developers																										
Standards development organizations (SDOs)	1	1	1		1		5					5		1	1			2	1						2	1
Testing laboratories																										
Universities		1	4	3	2	5	4	1	1	5		6	1	3	1			1	1						1	1

Exhibit 9.12: MN Correlation Matrix for Stage of Technological Innovation and Measurement Barriers in Materials

Stage of Technological Innovation	Measurement Solution Barriers															
	Acceptability/Compatibility	Accessibility	Accuracy	Data, Data Collection and/or Retrieval	Destructive	Expense	Lack of fundamental knowledge	Multiple Solutions Exist	Not Standardized	Production Readiness	Reliability	Resolution	Small Market Demand	Speed	System-Level Problem	Workforce
Applied Research	2	1	13	13	1	2	10	2	3	2	4	8		2		1
Production		2	6	4	1		2	1	1	1	1	2				
Market	1		2						2			1				
End-use																

Exhibit 9.13: MN Correlation Matrix for Stage of Technological Innovation and Measurement Solutions in Materials

	Measurement Solutions																								
	Infrastructure								Products													Services			
Stage of Technological Innovation	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Applied Research	1	1	12	5	3	7	6	3		7	2	11	2	4	2			2	1					1	1
Production	1		3	1	1	1	2		1	2		4			1			1			1				1
Market			1				2					1		1				1	1					1	
End-use																									

Exhibit 9.14: MN Correlation Matrix for Solution Providers and Stage of Technological Innovation in Materials

Measurement Solution Providers	Stage of Technological Innovation			
	Applied Research	Production	Market	End-use
Calibration laboratories				
Commercial calibration service providers				
Component suppliers	1			
Contractor R&D labs-for-hire				
Engineering management/consulting firms/A&E firms				
Government laboratories and agencies	20	6	1	
Independent testing/certification laboratories			2	
Industrial R&D laboratories	6	1	1	
Industry consortium/partnership	3	5	1	
Instrument suppliers	5	3	1	
Material suppliers	4	2		
National Measurement Institute	22	2	1	
Small business/inventors				
Software developers				
Standards development organizations (SDOs)	4	4	2	
Testing laboratories				
Universities	13	3		

Exhibit 9.15: MN Correlation Matrix for Stage of Technological Innovation and TI as Measurement Technology in Materials

Stage of Technological Innovation	TI as Measurement Technology
Applied Research	9
Production	1
Market	
End-use	

Exhibit 9.16: MN Correlation Matrix for TI as Measurement Technology and Measurement Barriers in Materials

Innovation Equivalency	Measurement Solution Barriers															
	Acceptability/Compatibility	Accessibility	Accuracy	Data, Data Collection and/or Retrieval	Destructive	Expense	Lack of fundamental knowledge	Multiple Solutions Exist	Not Standardized	Production Readiness	Reliability	Resolution	Small Market Demand	Speed	System-Level Problem	Workforce
Technology Innovation = Measurement Innovation	1		7	4			3			2		4		1		

Exhibit 9.17: MN Correlation Matrix for Solution Providers and TI as Measurement Technology in Materials

Measurement Solution Providers	Technology Innovation = Measurement Innovation
Calibration laboratories	
Commercial calibration service providers	
Component suppliers	
Contractor R&D labs-for-hire	
Engineering management/consulting firms/A&E firms	
Government laboratories and agencies	8
Independent testing/certification laboratories	
Industrial R&D laboratories	2
Industry consortium/partnership	2
Instrument suppliers	1
Material suppliers	2
National Measurement Institute	7
Small business/inventors	
Software developers	
Standards development organizations (SDOs)	2
Testing laboratories	
Universities	4

Exhibit 9.18: MN Correlation Matrix for TI as Measurement Technology and Measurement Solutions in Materials

	Measurement Solutions																							
	Infrastructure								Products													Services			
Innovation Equivalency	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Technology Innovation = Measurement Innovation			4		2		3	1				5	2	1	1										

Exhibit 9.19: MN Correlation Matrix for Regulation as Driver/Barrier and Measurement Solutions in Materials

	Measurement Solutions																								
	Infrastructure								Products														Services			
Regulatory Issues	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Regulation is a Driver			1			1	1		1			3		1											1
Regulation is a Barrier																		1	1					1	

Exhibit 9.20: MN Correlation Matrix for Solution Providers and Regulation as Driver/Barrier in Materials

Measurement Solution Providers	Regulation is a Driver	Regulation is a Barrier
Calibration laboratories		
Commercial calibration service providers		
Component suppliers		
Contractor R&D labs-for-hire		
Engineering management/consulting firms/A&E firms		
Government laboratories and agencies	1	
Independent testing/certification laboratories	1	1
Industrial R&D laboratories	1	
Industry consortium/partnership	1	
Instrument suppliers		
Material suppliers		
National Measurement Institute	3	1
Small business/inventors		
Software developers		
Standards development organizations (SDOs)	2	1
Testing laboratories		
Universities	2	

U.S. Measurement System

Measurement Need (MN) Data Book

Chapter 10. Nanotechnology

Prepared by
Energetics Incorporated
for the
National Institute of Standards and Technology

April 2006

Reference List of MN Distribution Charts and MN Correlation Matrices

Exhibit 10.1: MN Distribution of Measurement Barriers in Nanotechnology

Acceptibility	Accessibility	Accuracy	Data, Data Collection & Retrieval	Destructive	Expense	Lack of Fundamental Knowledge	Multiple Solutions	Not Standardized	Production Readiness	Reliability	Resolution	Small market demand	Speed	Systems-level	Workforce	Total
1	0	29	12	2	3	7	2	5	0	6	22	0	9	0	1	99

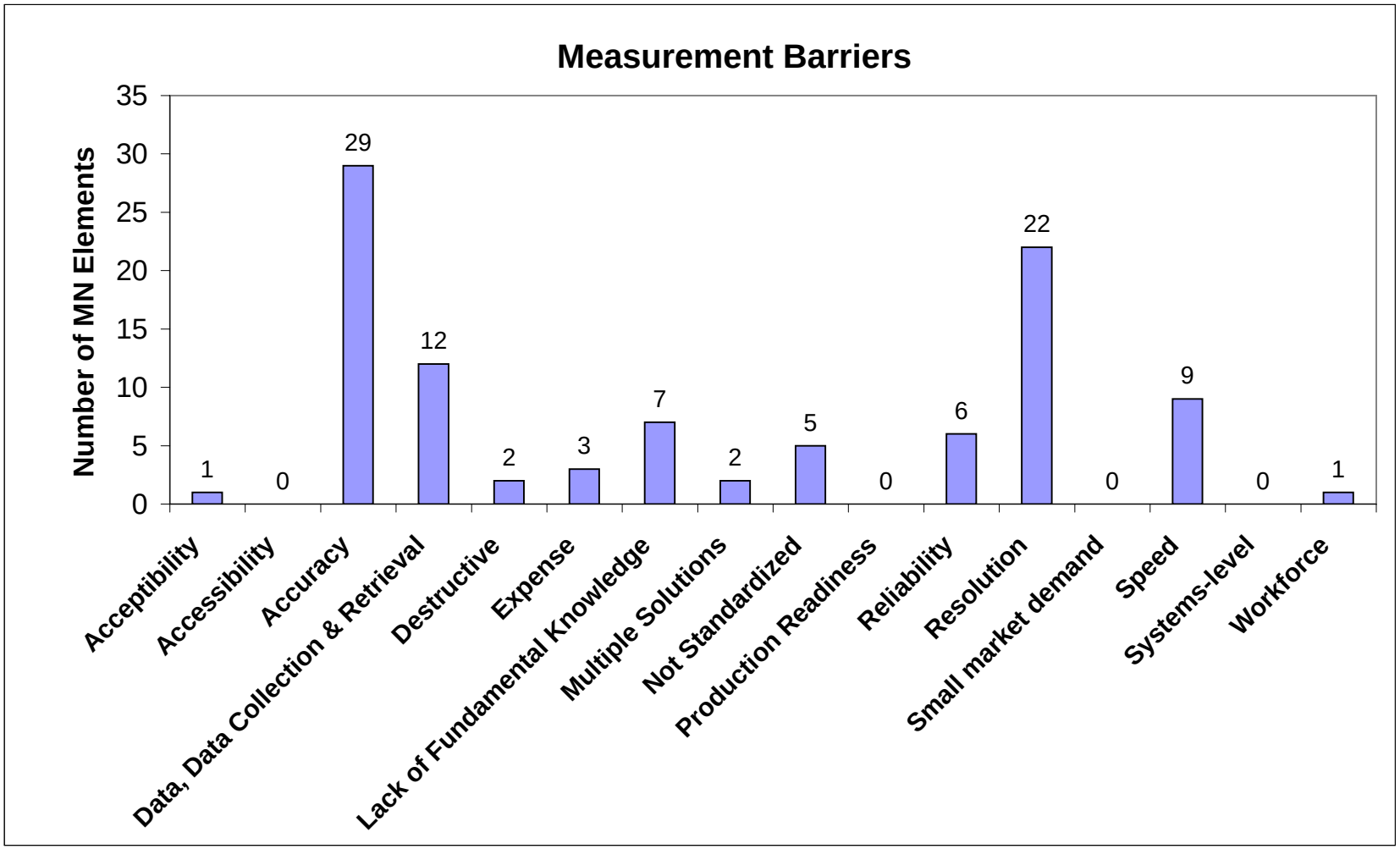

Exhibit 10.2: MN Distribution of Measurement Solution Providers in Nanotechnology

Calibration Laboratories	Commercial Calibration Service Providers	Component Suppliers	Contractor R&D Labs-for-Hire	Engineering Management/Consulting Firms/A&E Firms	Government Laboratories and Agencies	Independent Testing/Certification Laboratories	Industrial R&D Laboratories	Industry Consortium/ Partnership	Instrument Suppliers	Material Suppliers	National Measure-ment Institute	Small Business/Inventors	Software Developers	Standards Development Organizations (SDO)	Testing Laboratories	Universities	Total
1	0	0	0	0	25	1	6	11	11	6	24	0	1	1	0	15	102

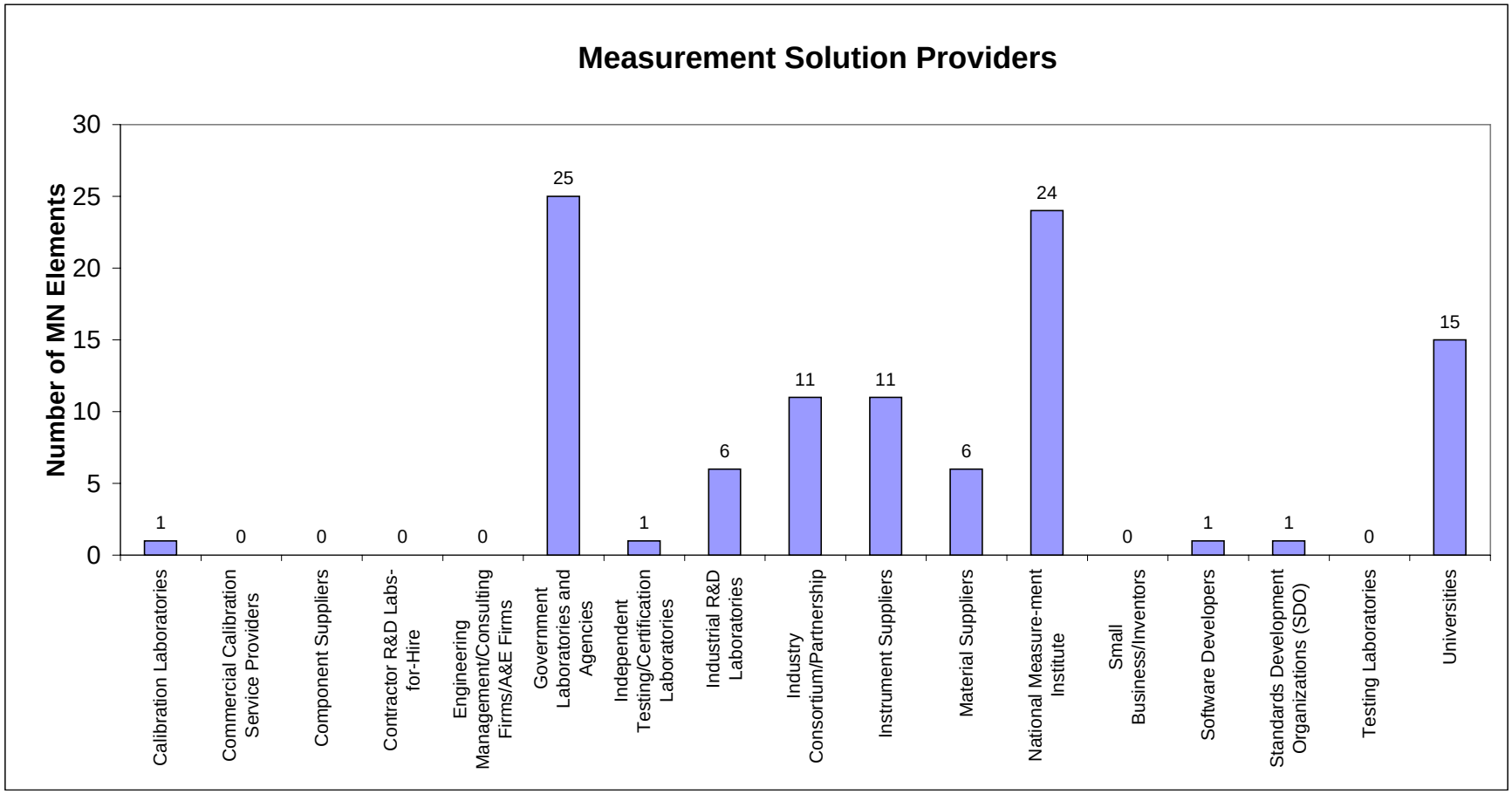

Exhibit 10.3: MN Distribution of Measurement Solutions in Nanotechnology

Infrastructure								Products													Services				
Coordination/Facilitation	Data Collection/Retrieval	Development - Measurement Technology	Fund-amental Knowledge	Pro-tocols	Research - Measure-ment Science	Standards	User Facility	Calibration	Computational Methods	Measure-ment Instru-ment	Measure-ment Method	Metrics/Benchmarks	Raw Data	Reference Data	Software	Stability Tests	Standard/certified reference material	Test methods for production-scale measurements	Test methods or test data for consumer products	Validated (hardened) properties data	Calibration	Expert consultation	Intl Recognition	Third Party Verification	Total
0	1	23	1	4	13	9	2	4	6	12	8	2	4	1	0	0	7	2	0	0	1	0	0	0	100

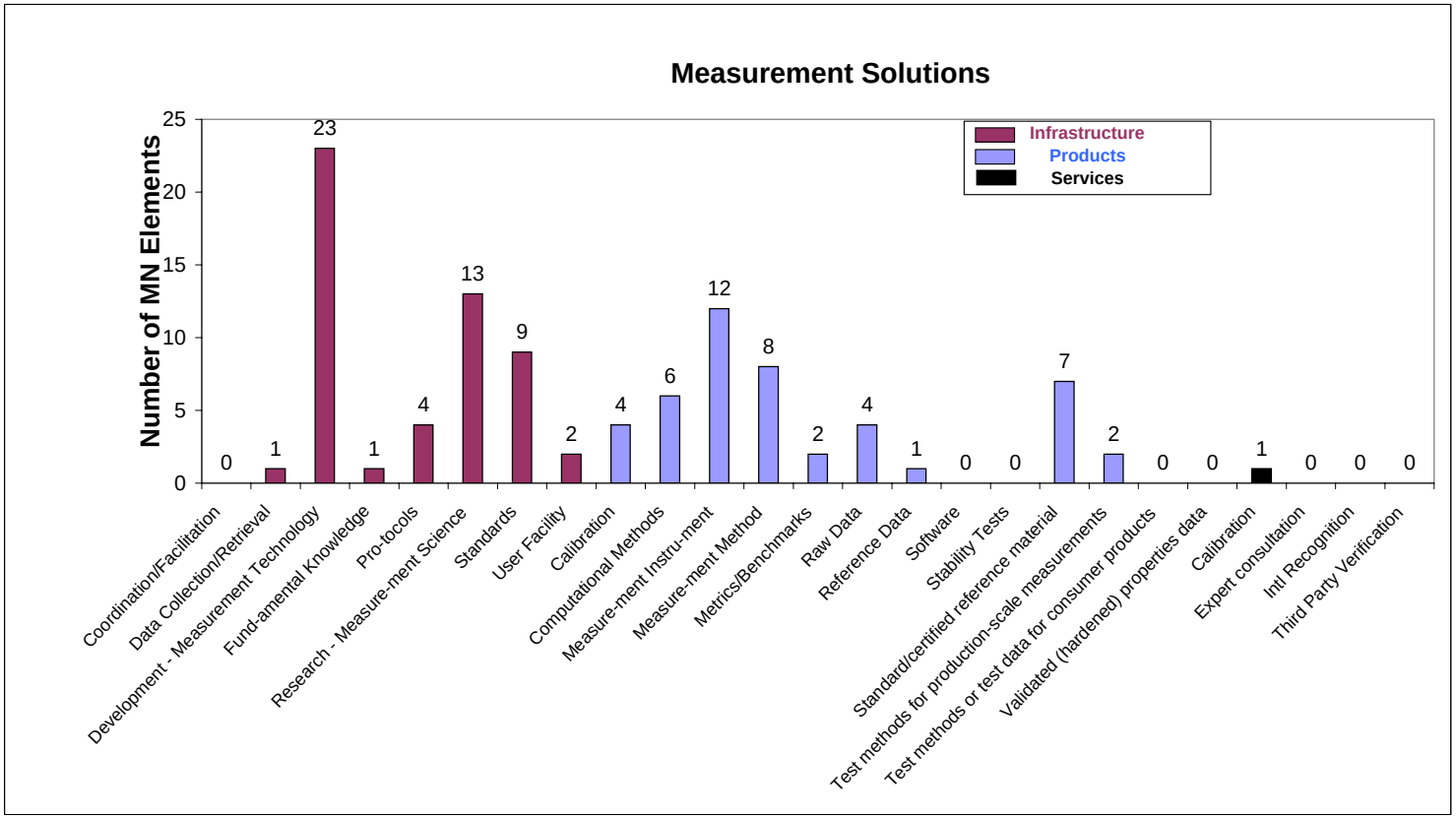

Exhibit 10.4: MN Distribution of Measurands in Nanotechnology

Classical				Functional									Performance			Structural				
Biological	Chemical	Physical	Physio-logical	Acoustical	Electronic/ Electrical	Magnetic	Optical	Photonic	Radio frequency	Thermal-Thermochemical	Thermal-Thermodynamic	Thermal-Thermophysical	Compu-tational Performance	Software Per-formance	System Per-formance	Kinetic	Mechanical	Molecular	Spatial	Total
0	5	19	1	0	3	1	3	1	0	0	0	1	0	0	0	0	1	1	0	36

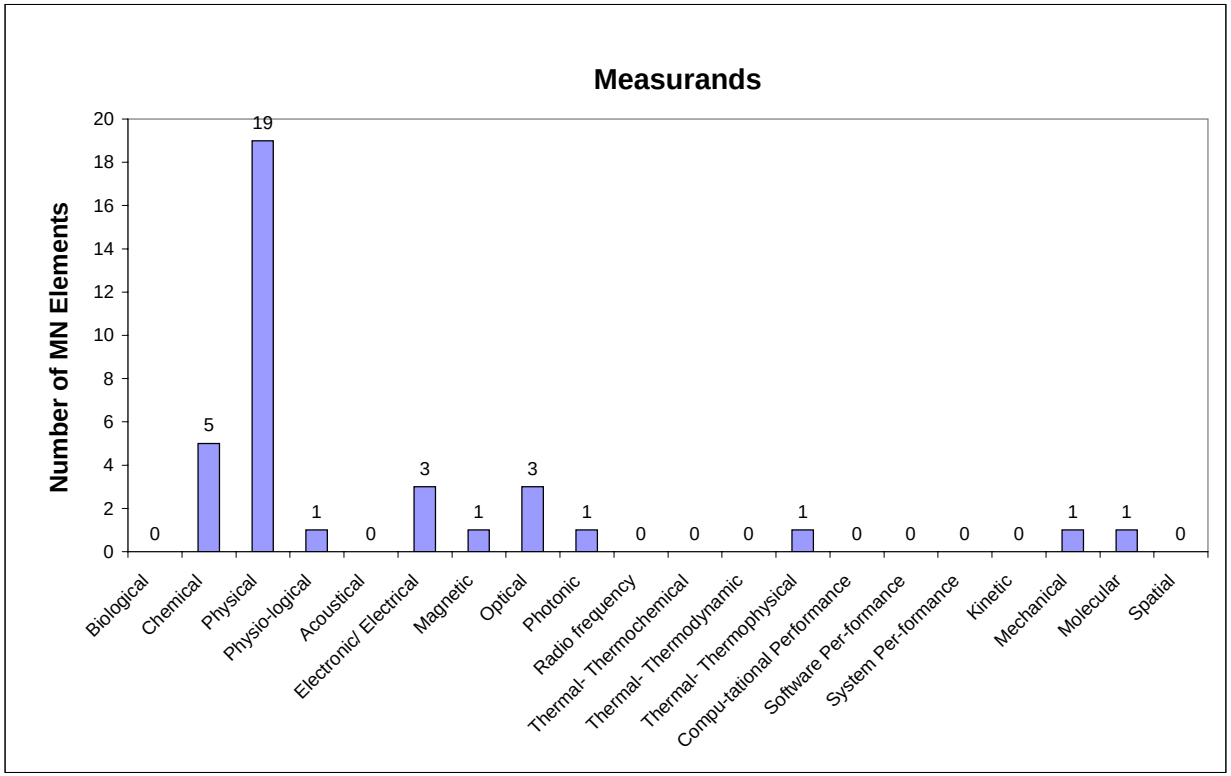

Exhibit 10.5: MN Distribution of Current Public/Private R&D Efforts in Nanotechnology

Only Private Efforts Exist	Only Public Efforts Exist	Both Public and Private Efforts Exist	No Efforts Exist
1	8	5	22

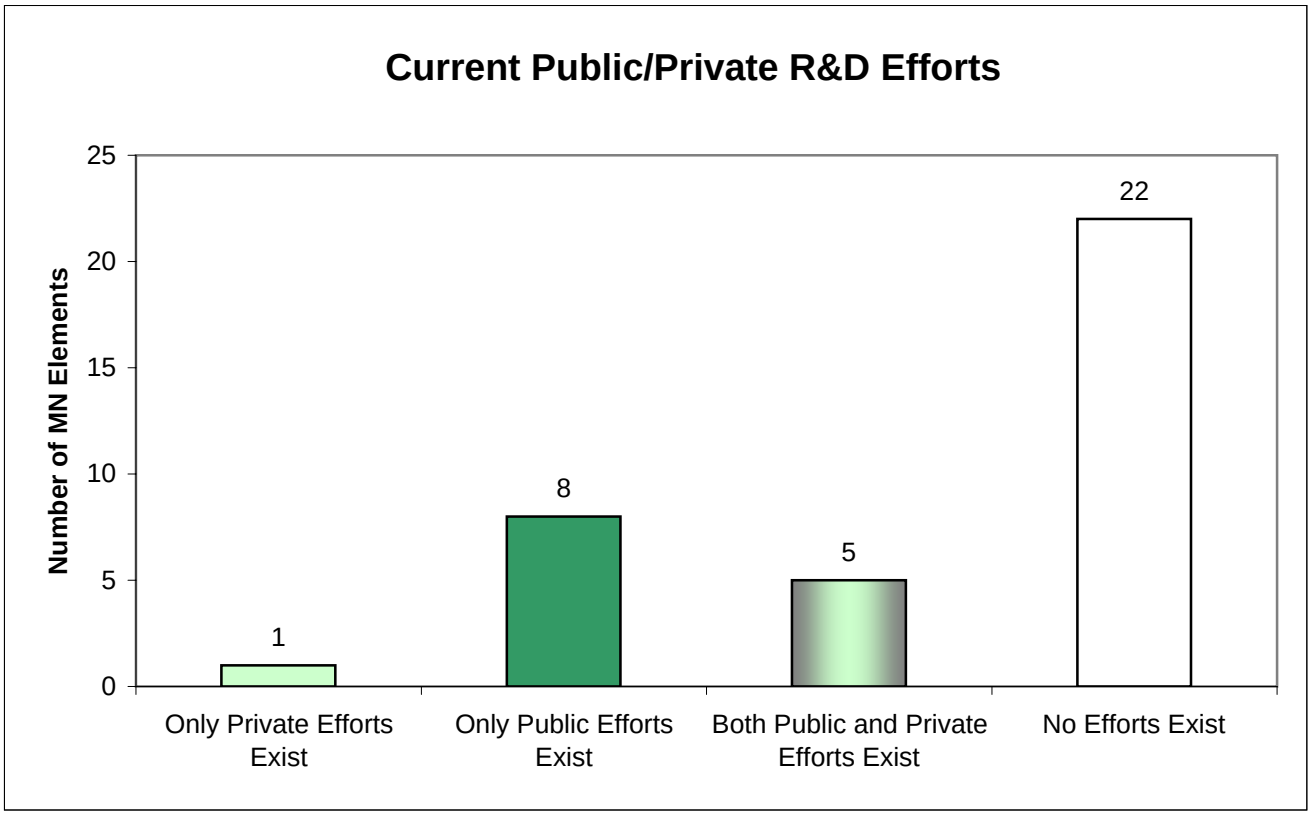

Exhibit 10.6: MN Distribution of TI as Measurement Technology in Nanotechnology

Technology Innovation is a Measurement Innovation	Technology Innovation is not a Measurement Innovation
15	21

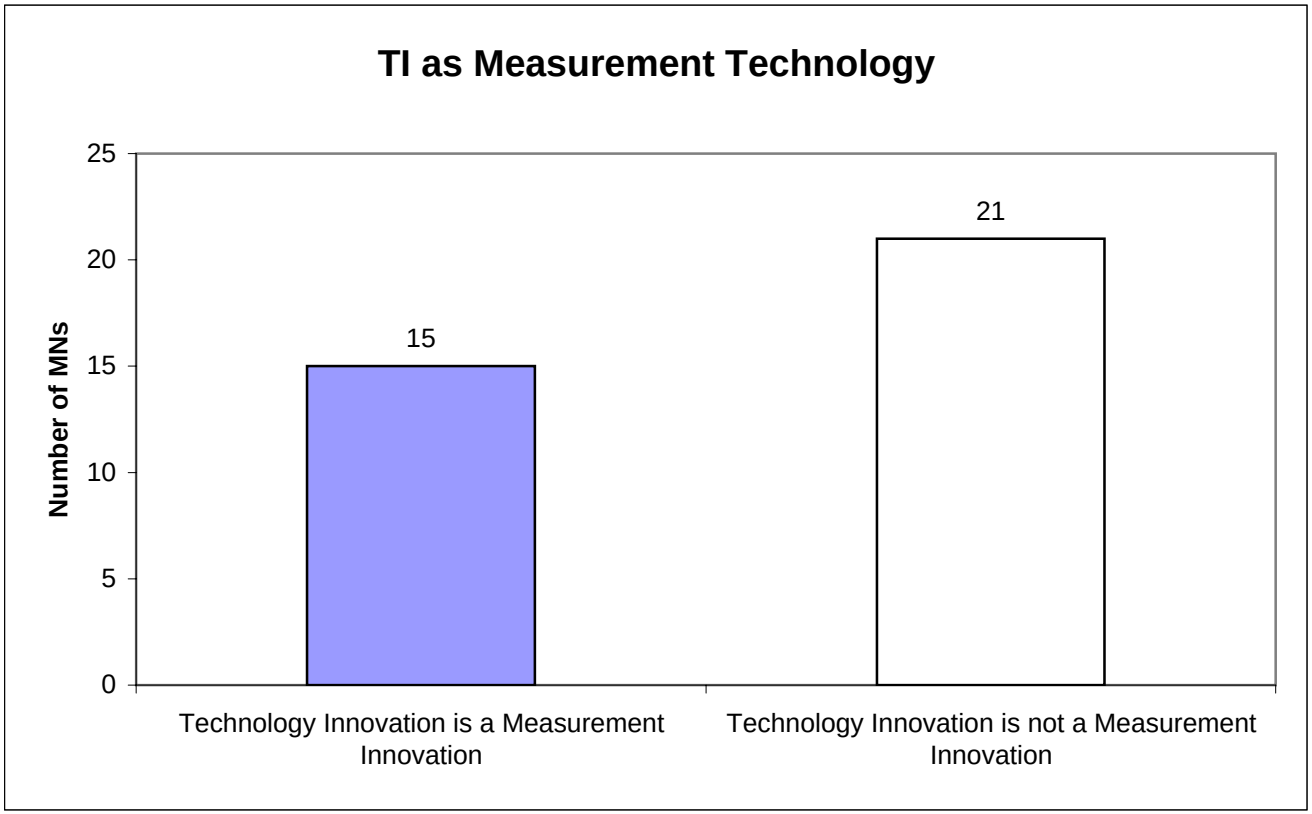

Exhibit 10.7: MN Distribution by Stage of Technological Innovation in Nanotechnology

Applied Research	Production	Market	End-use	Total
31	4	0	1	36

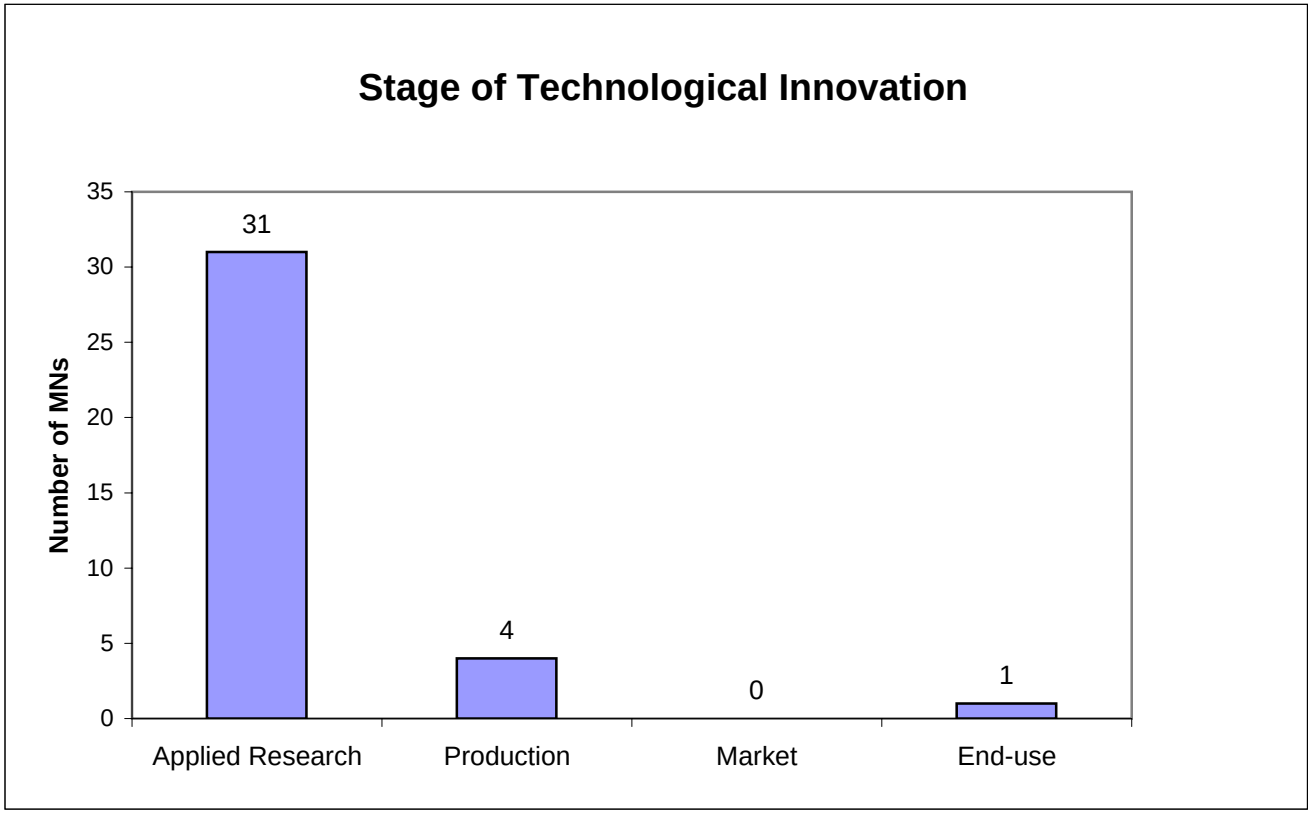

Exhibit 10.8: MN Distribution of Regulation as Driver/Barrier in Nanotechnology

MN Driver	MN Barrier	No Impact
1	0	35

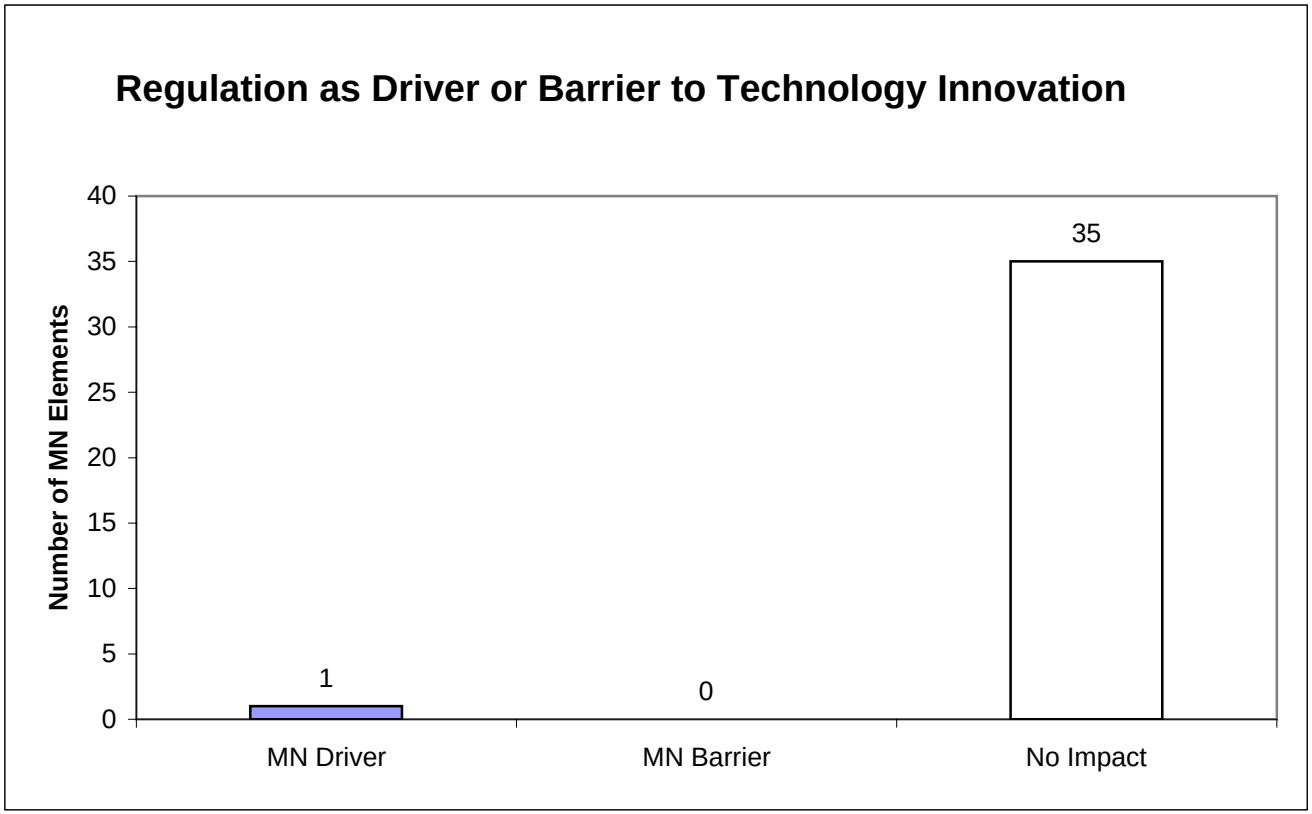

Exhibit 10.9: MN Correlation Matrix for Solution Providers and Measurement Barriers in Nanotechnology

Solution Providers	Measurement Solution Barriers															
	Acceptability/Compatibility	Accessibility	Accuracy	Data, Data Collection and/or Retrieval	Destructive	Expense	Lack of fundamental knowledge	Multiple Solutions Exist	Not Standardized	Production Readiness	Reliability	Resolution	Small Market Demand	Speed	System-Level Problem	Workforce
Calibration laboratories			1			1										
Commercial calibration service providers																
Component suppliers																
Contractor R&D labs-for-hire																
Engineering management/consulting firms/A&E firms																
Government laboratories and agencies	1		19	8	1	3	5	1	1		3	18		8		1
Independent testing/certification laboratories				1					1					1		
Industrial R&D laboratories	1		5	2	1		2		1			5		1		
Industry consortium/partnership			10	3	1	1	1	1			3	7		5		
Instrument suppliers			10	4	1	1	2	1	3		2	5		2		
Material suppliers	1		4	4			2	1	2		1	1		1		
National Measurement Institute			20	7		2	5	1	4		5	15		5		1
Small business/inventors																
Software developers			1									1				
Standards development organizations (SDOs)			1	1								1				
Testing laboratories																
Universities			11	5	2	1	3	1			2	11		4		1

Exhibit 10.10: MN Correlation Matrix for Measurement Barriers and Measurement Solutions in Nanotechnology

	Measurement Solutions																								
	Infrastructure								Products														Services			
Measurement Solution Barriers	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Acceptability/Compatibility			1		1									1											
Accessibility																									
Accuracy		1	20		2	11	8	2	3	3	10	5	2	3	1			5	2			1			
Data, Data Collection/and or Retrieval		1	5		4	3	3	1	2	3	3	3	1	3	1			3							
Destructive						1				1	2	2													
Expense			3			3	1				1							1							
Lack of Fundamental Knowledge			5	1	1	3	1		1	2	1	1	1	2				1							
Multiple Solutions Exist			2			1	1		1			1													
Not Standardized			1		2		3		2	1	1	1						3							
Production Readiness																									
Reliability			4			3	2		1	1	3				1			2				1			
Resolution		1	15		1	8	4	2	1	3	9	6	2	2				2	2						
Small Market Demand																									
Speed			6		1	4	2			1	5	1						2	1						
System-Level Problem																									
Workforce																									

Exhibit 10.11: MN Correlation Matrix for Measurement Providers and Measurement Solutions in Nanotechnology

	Measurement Solutions																									
	Infrastructure								Products														Services			
Measurement Solution Providers	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Calibration laboratories			1			1												1								
Commercial calibration service providers																										
Component suppliers																										
Contractor R&D labs-for-hire																										
Engineering management/consulting firms/A&E firms																										
Government laboratories and agencies		1	19	1	3	10	6	2	1	3	6	5	2	4				4	2							
Independent testing/certification laboratories					1		1											1								
Industrial R&D laboratories		1	4		2	1				1	2	1	1	2				1								
Industry consortium/partnership			7			6	2		1	1	8	1			1			2	1							
Instrument suppliers			7		1	4	5	2	3	2	3	2						1	1							
Material suppliers			4		2	3	4		1	1				2				1								
National Measurement Institute			15	1	1	7	6	2	4	4	10	6	2	1	1			6				1				
Small business/inventors																										
Software developers										1		1														
Standards development organizations (SDOs)		1	1		1																					
Testing laboratories																										
Universities			9	1		7	2		1	3	4	6	1	3	1			2	2							

Exhibit 10.12: MN Correlation Matrix for Stage of Technological Innovation and Measurement Barriers in Nanotechnology

Stage of Technological Innovation	Measurement Solution Barriers															
	Acceptability/Compatibility	Accessibility	Accuracy	Data, Data Collection and/or Retrieval	Destructive	Expense	Lack of fundamental knowledge	Multiple Solutions Exist	Not Standardized	Production Readiness	Reliability	Resolution	Small Market Demand	Speed	System-Level Problem	Workforce
Applied Research	1		25	9	2	2	6	1	3		5	22		8		1
Production			3	3			1	1	2		1			1		
Market																
End-use			1			1										

Exhibit 10.13: MN Correlation Matrix for Stage of Technological Innovation and Measurement Solutions in Nanotechnology

Stage of Technological Innovation	Measurement Solutions																									
	Infrastructure								Products															Services			
	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Applied Research		1	20	1	3	11	6	2	3	6	11	8	2	4				4	2			1			
Production			2		1	1	3		1		1				1			2							
Market																									
End-use			1			1												1							

Exhibit 10.14: MN Correlation Matrix for Solution Providers and Stage of Technological Innovation in Nanotechnology

Measurement Solution Providers	Stage of Technological Innovation			
	Applied Research	Production	Market	End-Use
Calibration laboratories				1
Commercial calibration service providers				
Component suppliers				
Contractor R&D labs-for-hire				
Engineering management/consulting firms/A&E firms				
Government laboratories and agencies	23	1		1
Independent testing/certification laboratories		1		
Industrial R&D laboratories	6			
Industry consortium/partnership	9	2		
Instrument suppliers	9	2		
Material suppliers	3	3		
National Measurement Institute	21	2		1
Small business/inventors				
Software developers	1			
Standards development organizations (SDOs)	1			
Testing laboratories				
Universities	14	1		

Exhibit 10.15: MN Correlation Matrix for Stage of Technological Innovation and TI as Measurement Technology in Nanotechnology

Stage of Technological Innovation	TI as Measurement Technology
Applied Research	12
Production	2
Market	
End-use	1

Exhibit 10.16: MN Correlation Matrix for TI as Measurement Technology and Measurement Barriers in Nanotechnology

	Measurement Solution Barriers															
Innovation Equivalency	**Acceptability/Compatibility**	**Accessibility**	**Accuracy**	**Data, Data Collection and/or Retrieval**	**Destructive**	**Expense**	**Lack of fundamental knowledge**	**Multiple Solutions Exist**	**Not Standardized**	**Production Readiness**	**Reliability**	**Resolution**	**Small Market Demand**	**Speed**	**System-Level Problem**	**Workforce**
Technology Innovation = Measurement Innovation	1		13	4	1	2	3	1	2		3	9		2		

Exhibit 10.17: MN Correlation Matrix for Solution Providers and TI as Measurement Technology in Nanotechnology

Measurement Solution Providers	Technology Innovation = Measurement Innovation
Calibration laboratories	1
Commercial calibration service providers	
Component suppliers	
Contractor R&D labs-for-hire	
Engineering management/consulting firms/A&E firms	
Government laboratories and agencies	11
Independent testing/certification laboratories	1
Industrial R&D laboratories	3
Industry consortium/partnership	1
Instrument suppliers	4
Material suppliers	4
National Measurement Institute	9
Small business/inventors	
Software developers	1
Standards development organizations (SDOs)	
Testing laboratories	
Universities	7

Exhibit 10.18: MN Correlation Matrix for TI as Measurement Technology and Measurement Solutions in Nanotechnology

	Measurement Solutions																								
	Infrastructure								Products														Services			
Innovation Equivalency	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Technology Innovation = Measurement Innovation			11		2	6	5		2	2	2	4	2	2				3				1			

Exhibit 10.19: MN Correlation Matrix for Regulation as Driver/Barrier and Measurement Solutions in Nanotechnology

	Measurement Solutions																										
	Infrastructure								Products														Services				
Regulatory Issues	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Regulation is a Driver			1			1												1							
Regulation is a Barrier																									

Exhibit 10.20: MN Correlation Matrix for Solution Providers and Regulation as Driver/Barrier in Nanotechnology

Measurement Solution Providers	Regulation is a Driver	Regulation is a Barrier
Calibration laboratories	1	
Commercial calibration service providers		
Component suppliers		
Contractor R&D labs-for-hire		
Engineering management/consulting firms/A&E firms		
Government laboratories and agencies	1	
Independent testing/certification laboratories		
Industrial R&D laboratories		
Industry consortium/partnership		
Instrument suppliers		
Material suppliers		
National Measurement Institute	1	
Small business/inventors		
Software developers		
Standards development organizations (SDOs)		
Testing laboratories		
Universities		

U.S. Measurement System

Measurement Need (MN) Data Book

Chapter 11. Software for Information Technology

Prepared by
Energetics Incorporated
for the
National Institute of Standards and Technology

April 2006

Reference List of MN Distribution Charts and MN Correlation Matrices

Exhibit 11.1: MN Distribution of Measurement Barriers in Software for Information Technology

Acceptibility	Accessibility	Accuracy	Data, Data Collection & Retrieval	Destructive	Expense	Lack of Fundamental Knowledge	Multiple Solutions	Not Standardized	Production Readiness	Reliability	Resolution	Small market demand	Speed	Systems-level	Workforce	Total
9	3	13	13	0	0	8	1	15	1	10	0	0	2	0	0	75

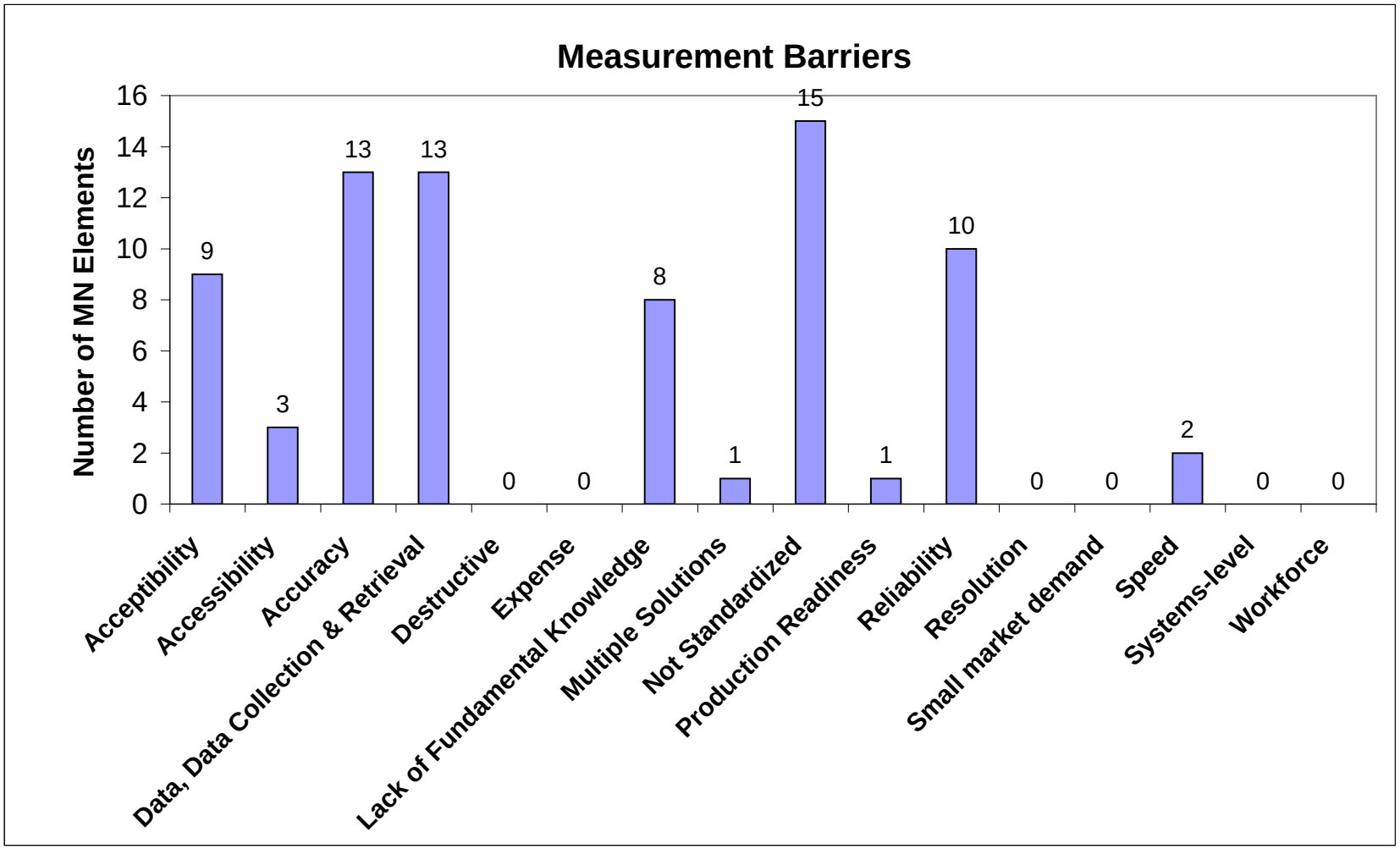

Exhibit 11.2: MN Distribution of Measurement Solution Providers in Software for Information Technology

Calibration Laboratories	Commercial Calibration Service Providers	Component Suppliers	Contractor R&D Labs-for-Hire	Engineering Management/Consulting Firms/A&E Firms	Government Laboratories and Agencies	Independent Testing/Certification Laboratories	Industrial R&D Laboratories	Industry Consortium/ Partnership	Instrument Suppliers	Material Suppliers	National Measurement Institute	Small Business/Inventors	Software Developers	Standards Development Organizations (SDO)	Testing Laboratories	Universities	Total
0	0	2	2	1	22	1	13	5	2	0	23	0	8	1	0	14	94

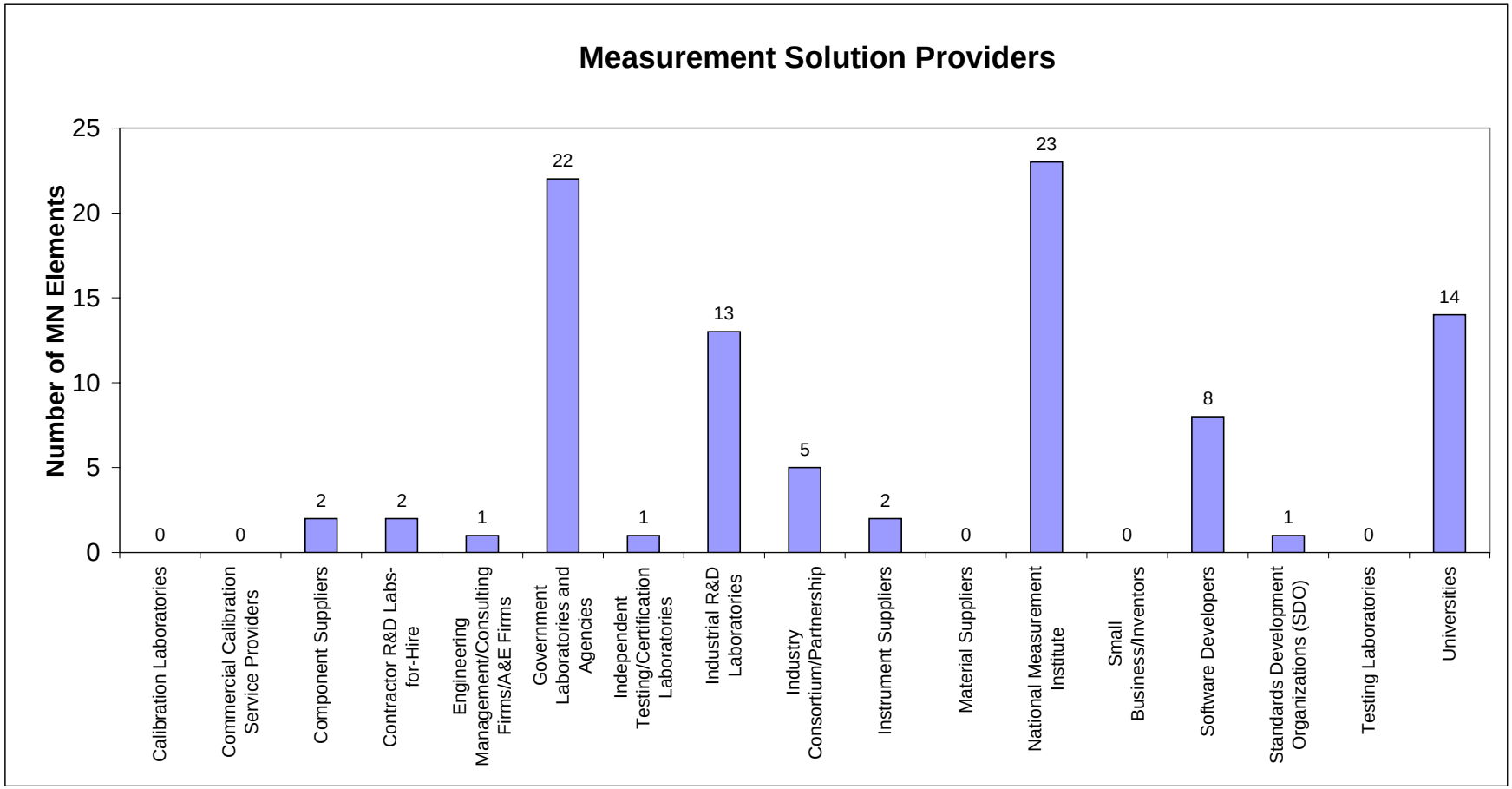

Exhibit 11.3: MN Distribution of Measurement Solutions in Software for Information Technology

Infrastructure								Products												Services				
Coordination/Facilitation	Data Collection/Retrieval	Development - Measurement Technology	Fund-amental Knowledge	Protocols	Research - Measure-ment Science	Standards	User Facility	Calibration	Computational Methods	Measure-ment Instrument	Measure-ment Method	Metrics/Benchmarks	Raw Data	Reference Data	Software	Stability Tests	Standard/certified reference material	Test methods for production-scale measurements	Test methods or test data for consumer products	Validated (hardened) properties data	Calibration	Expert consultation	Intl Recognition	Third Party Verification	Total
4	3	5	2	5	5	8	1	1	7	1	8	15	1	9	3	0	1	1	3	1	0	1	0	1	86

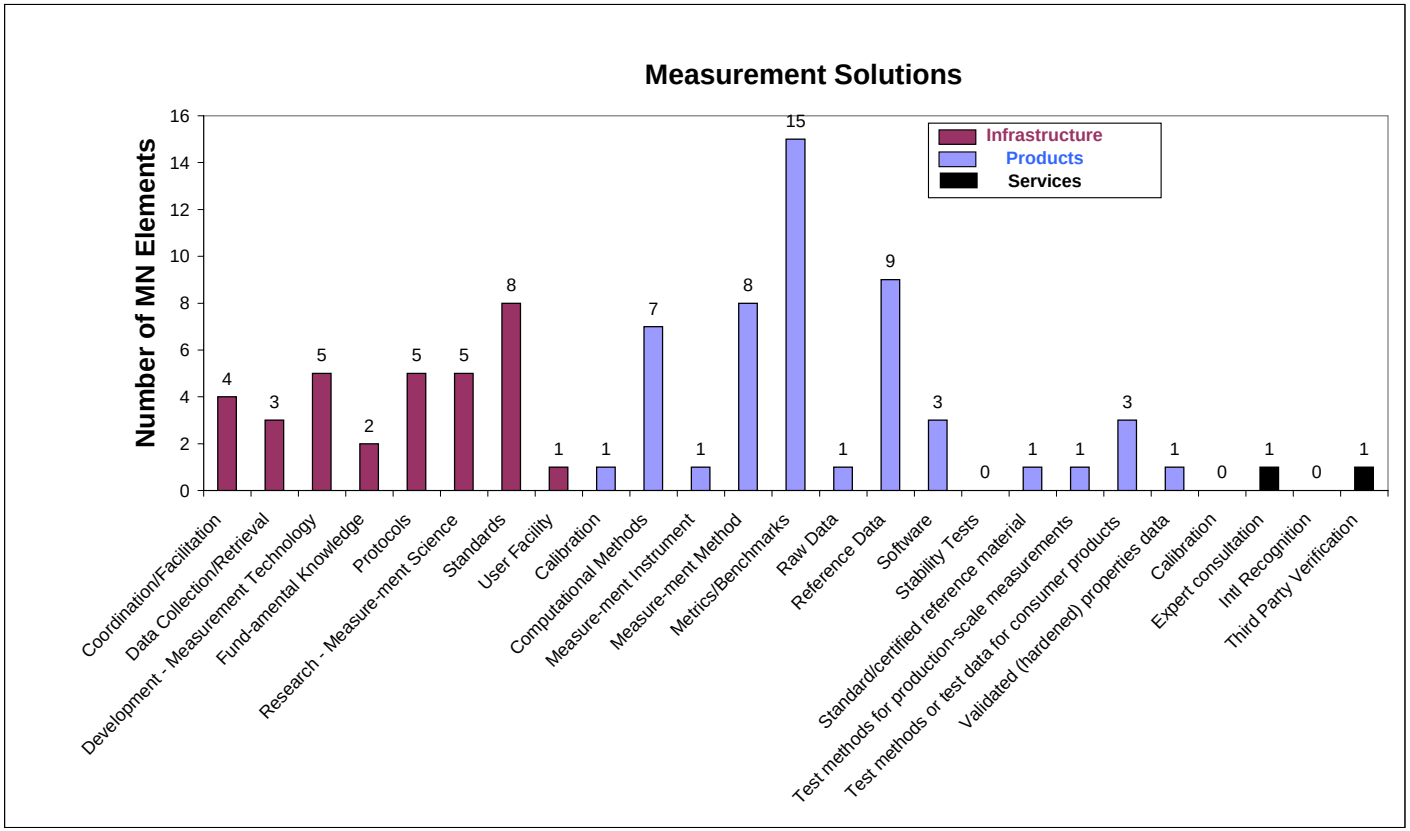

Exhibit 11.4: MN Distribution of Measurands in Software for Information Technology

Classical				Functional									Performance			Structural				
Biological	Chemical	Physical	Physio-logical	Acoustical	Electronic/ Electrical	Magnetic	Optical	Photonic	Radio frequency	Thermal-Thermochemical	Thermal-Thermodynamic	Thermal-Thermophysical	Compu-tational Performance	Software Performance	System Performance	Kinetic	Mechanical	Molecular	Spatial	Total
0	0	4	0	2	1	0	1	0	1	0	0	1	5	10	7	0	0	0	1	33

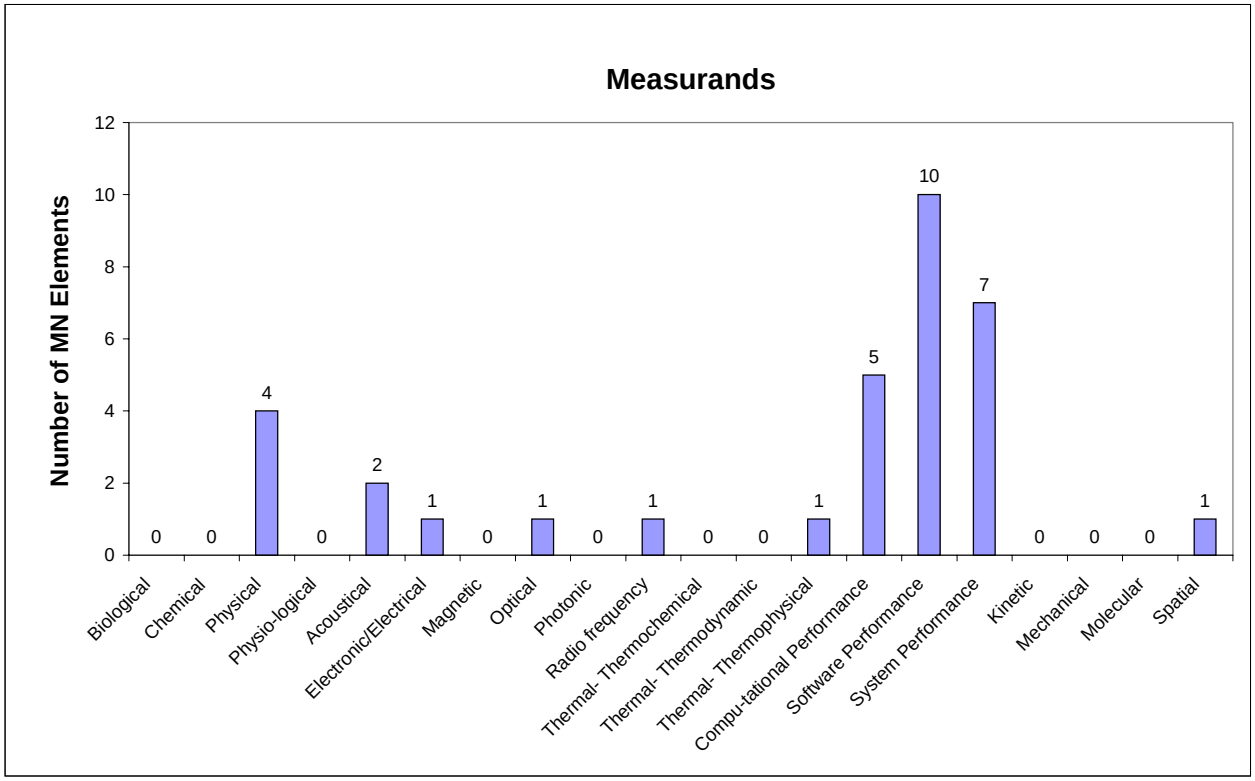

Exhibit 11.5: MN Distribution of Current Public/Private R&D Efforts in Software for Information Technology

Only Private Efforts Exist	Only Public Efforts Exist	Both Public and Private Efforts Exist	No Efforts Exist
1	3	8	21

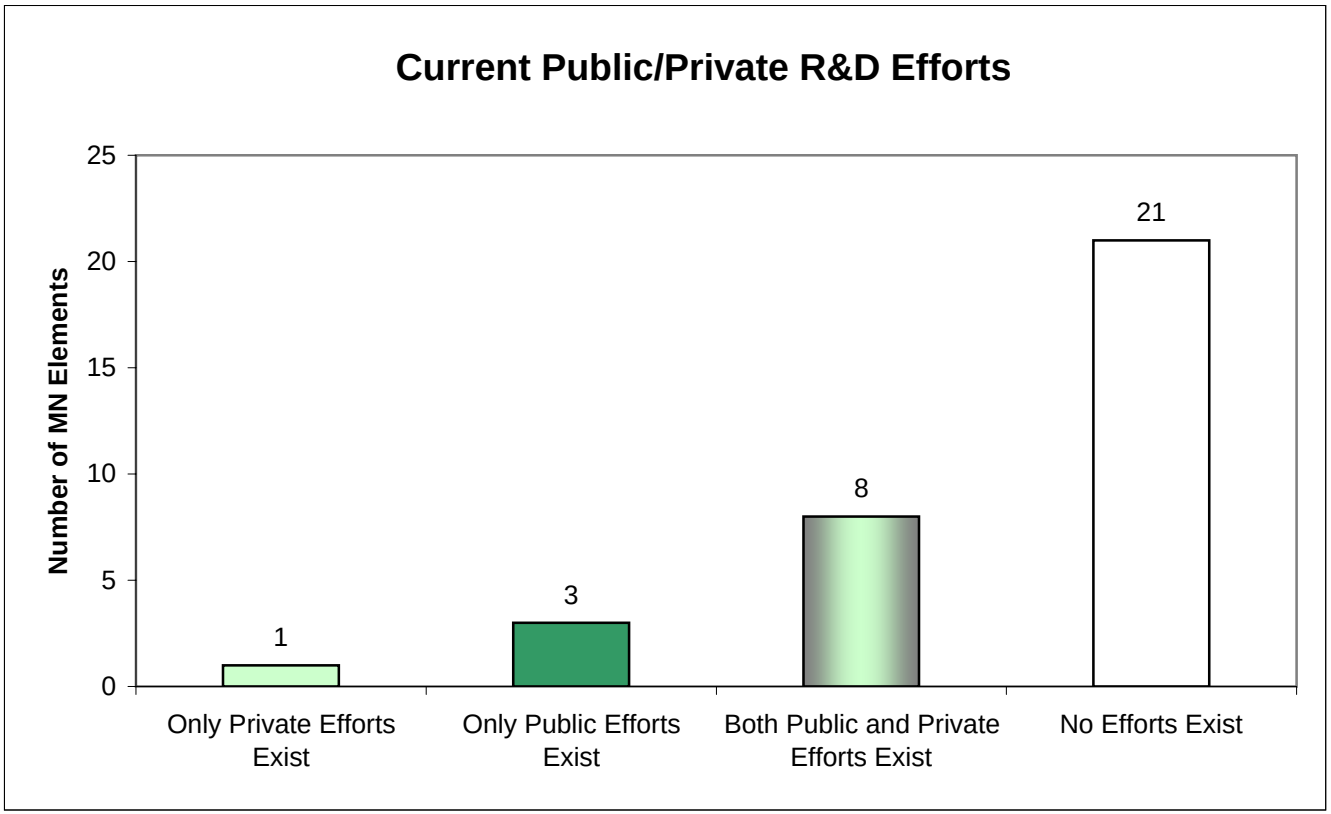

Exhibit 11.6: MN Distribution of TI as Measurement Technology in Software for Information Technology

Technology Innovation is a Measurement Innovation	Technology Innovation is not a Measurement Innovation
12	21

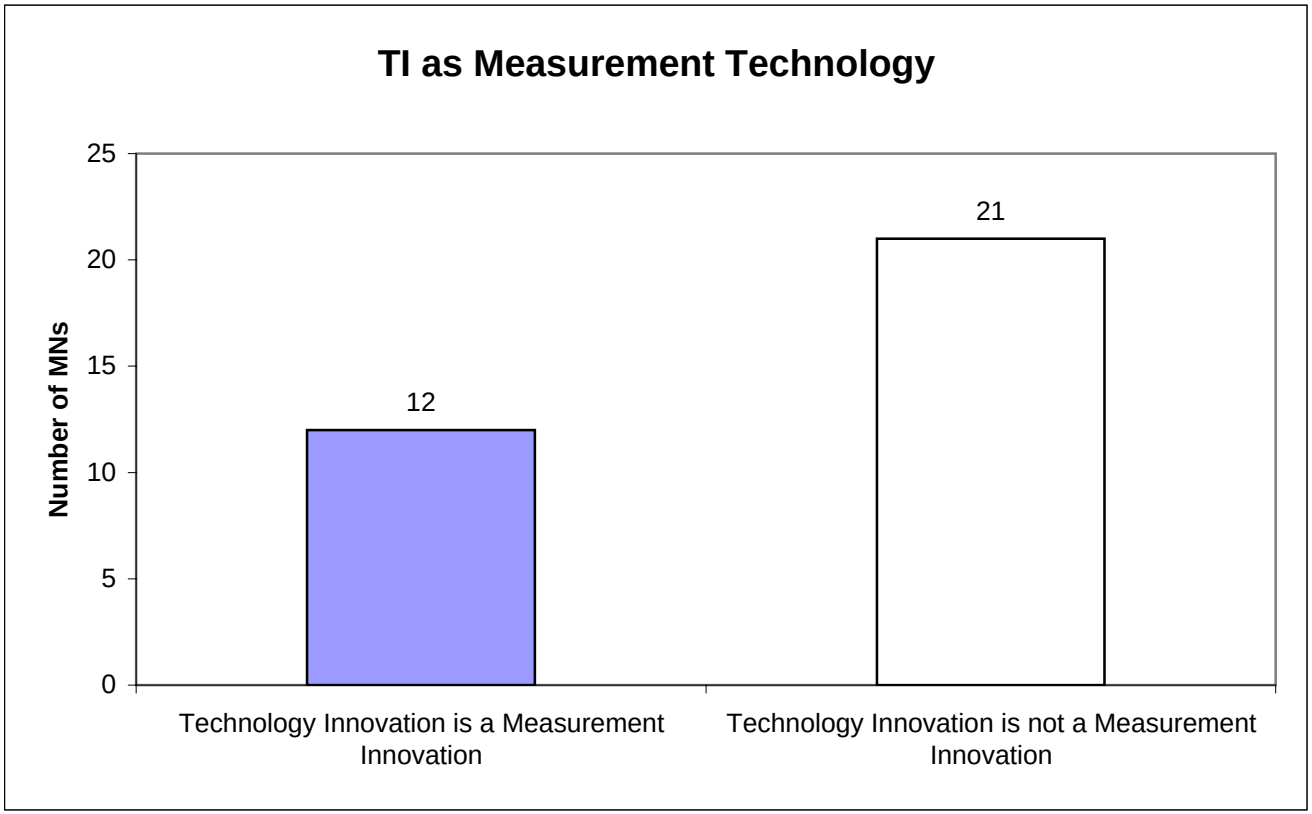

Exhibit 11.7: MN Distribution by Stage of Technological Innovation in Software for Information Technology

Applied Research	Production	Market	End-use	Total
21	4	5	3	33

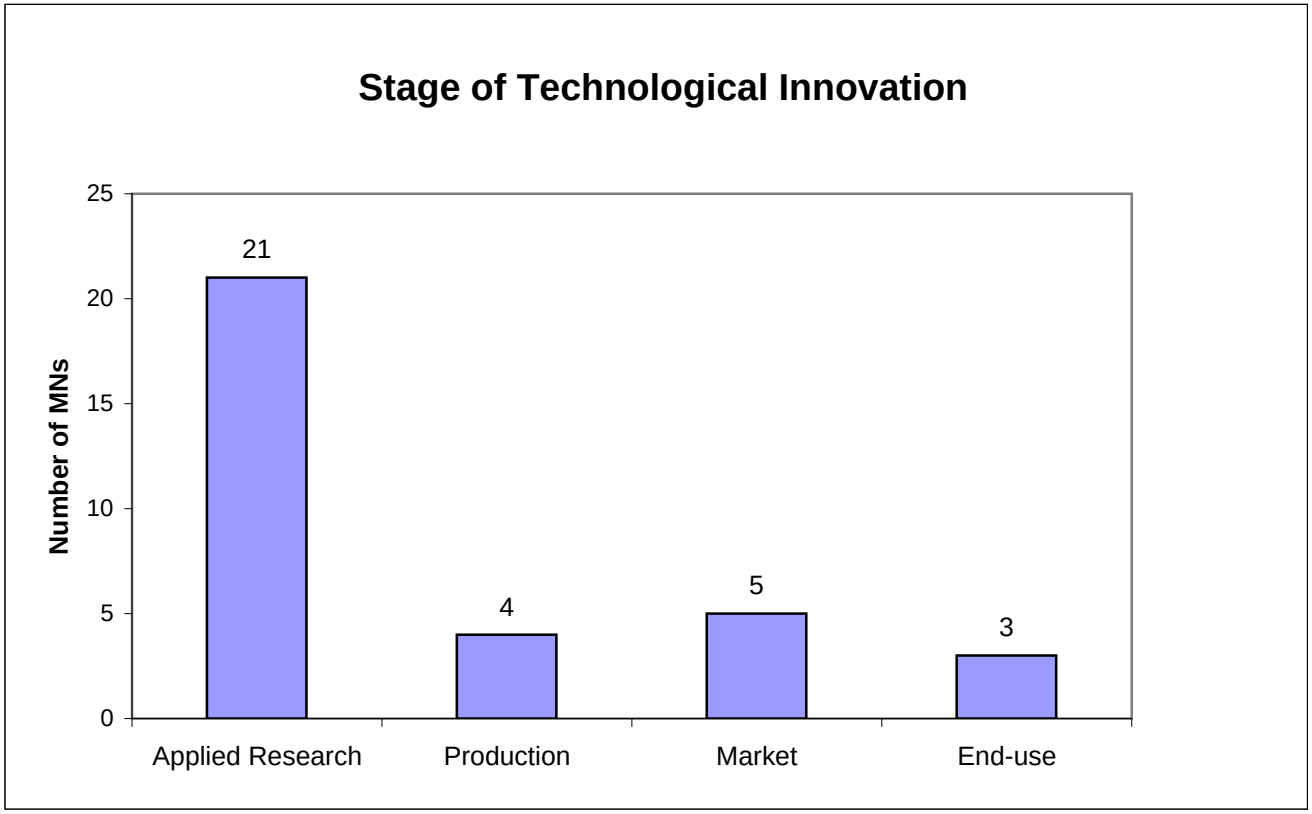

Exhibit 11.8: MN Distribution of Regulation as Driver/Barrier in Software for Information Technology

MN Driver	MN Barrier	No Impact
4	0	29

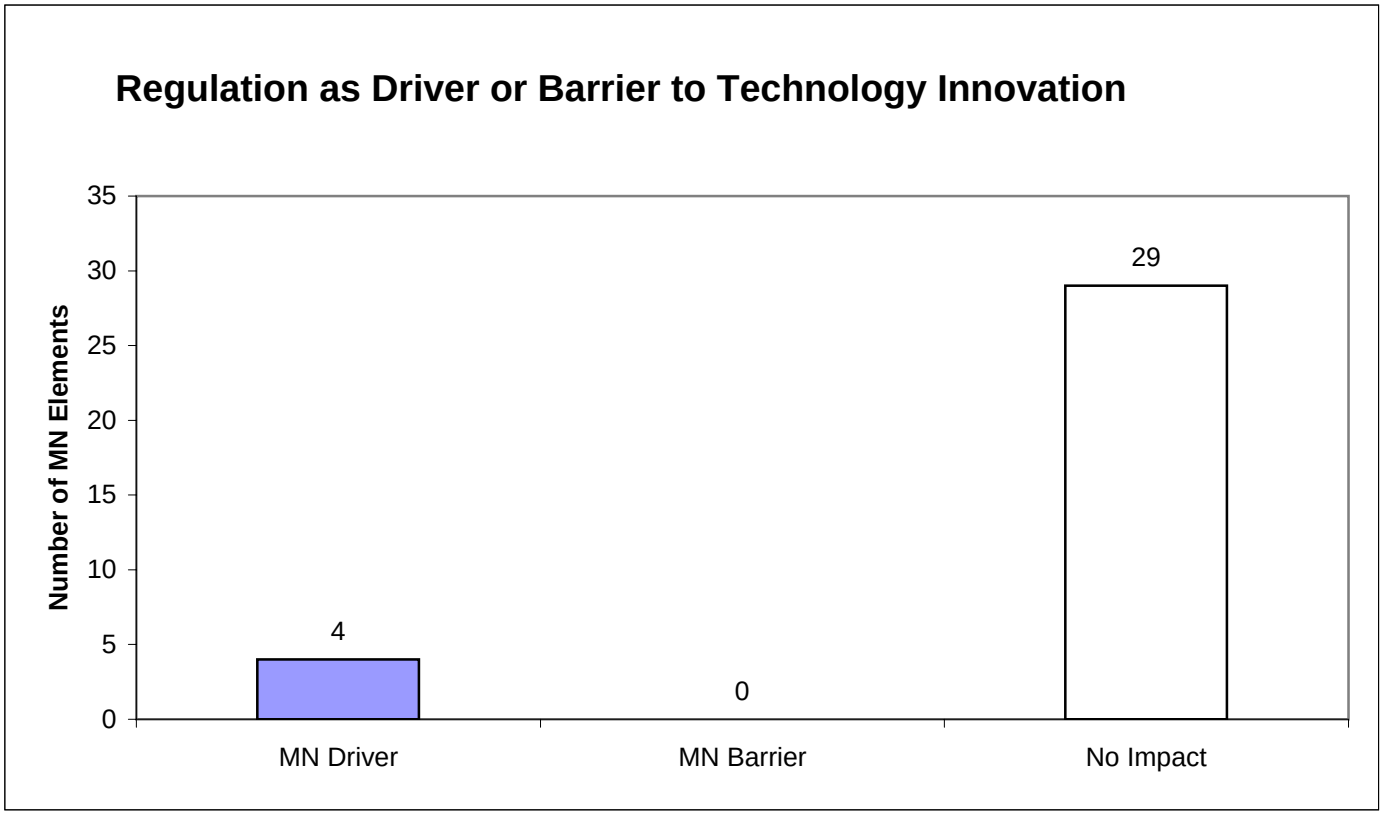

Exhibit 11.9: MN Correlation Matrix for Solution Providers and Measurement Barriers in Software for Information Technology

Solution Providers	Measurement Solution Barriers															
	Acceptability/Compatibility	Accessibility	Accuracy	Data, Data Collection and/or Retrieval	Destructive	Expense	Lack of fundamental knowledge	Multiple Solutions Exist	Not Standardized	Production Readiness	Reliability	Resolution	Small Market Demand	Speed	System-Level Problem	Workforce
Calibration laboratories																
Commercial calibration service providers																
Component suppliers	2		1	1												
Contractor R&D labs-for-hire	1		2	1							2					
Engineering management/consulting firms/A&E firms		1														
Government laboratories and agencies	6		8	6			6	1	12	1	7			1		
Independent testing/certification laboratories											1					
Industrial R&D laboratories	2		2	2			6		6	1	2			1		
Industry consortium/partnership	4	1	1	2			1		5							
Instrument suppliers	2	1	1	1					1							
Material suppliers																
National Measurement Institute	6	3	8	8			6	1	14	1	6			1		
Small business/inventors																
Software developers	2	2	5	5			1		1		4					
Standards development organizations (SDOs)				1							1					
Testing laboratories																
Universities	2	1	7	8			4	1	2		6			2		

Exhibit 11.10: MN Correlation Matrix for Measurement Barriers and Measurement Solutions in Software for Information Technology

	Measurement Solutions																								
	Infrastructure								Products													Services			
Measurement Solution Barriers	**Coordination/ facilitation**	**Data Collection/ Retrieval**	**Development for Measurement Technology**	**Fundamental Scientific Knowledge**	**Protocols**	**Research for Measurement Science**	**Standards**	**User Facility**	**Calibration Method**	**Computation Method**	**Measurement Instrument**	**Measurement Method**	**Metrics/ Benchmarks**	**Raw Properties Data**	**Reference Data**	**Software**	**Stability Tests**	**Standard/CRM**	**Test Methods - Production Scale**	**Test Methods - Consumer Products**	**Validated Data**	**Calibration Services**	**Expert Consultation**	**International Recognition**	**3rd Party Verification**
Acceptability/Compatibility	1		2		3	2	5		1	1		2	2		2	2			1						
Accessibility	1	1			1		1			1		1			1	1									
Accuracy	2	1	2	1		2	3	1	1	4		4	8		2	1		1		3			1		
Data, Data Collection/and or Retrieval	2	3	1	1	2	1	2	1		5	1	4	5	1	4	1		1		2	1				1
Destructive																									
Expense																									
Lack of Fundamental Knowledge	1	1	1	1	2	3	2			2		2	4		3										
Multiple Solutions Exist											1	1		1											
Not Standardized	2	1	3	1	3	2	5	1	1	2	1	2	5	1	5	2				1	1		1		
Production Readiness													1												
Reliability	2	1	1	1			2			2		2	7		3			1		2			1		1
Resolution																									
Small Market Demand																									
Speed			1				1					1	1		1										
System-Level Problem																									
Workforce																									

Exhibit 11.11: MN Correlation Matrix for Measurement Providers and Measurement Solutions in Software for Information Technology

Measurement Solution Providers	Measurement Solutions																									
	Infrastructure								Products														Services			
	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Calibration laboratories																										
Commercial calibration service providers																										
Component suppliers					1					1		1	1						1							
Contractor R&D labs-for-hire	1						1					1	1							1						
Engineering management/consulting firms/A&E firms												1				1										
Government laboratories and agencies	3	1	3	2	3	5	4		1	3	1	3	11	1	6	2		1	1	3			1			
Independent testing/certification laboratories													1													
Industrial R&D laboratories	1		3	1	3	3	2			3		2	7		4				1	1						
Industry consortium/partnership	1	1	1		2	1	3		1	1					1	2					1					
Instrument suppliers	1				1		1			1		1	1													
Material suppliers																										
National Measurement Institute	1	2	5	2	4	2	7	1	1	3	1	6	10	1	6	3		1		1	1		1			
Small business/inventors																										
Software developers	1	2		1		1	1			3		2	4		3	1		1		1						1
Standards development organizations (SDOs)							1								1											1
Testing laboratories																										
Universities	3	2	2		1	3	3			5	1	5	6	1	4					2						1

Exhibit 11.12: MN Correlation Matrix for Stage of Technological Innovation and Measurement Barriers in Software for Information Technology

Stage of Technological Innovation	Measurement Solution Barriers															
	Acceptability/Compatibility	Accessibility	Accuracy	Data, Data Collection and/or Retrieval	Destructive	Expense	Lack of fundamental knowledge	Multiple Solutions Exist	Not Standardized	Production Readiness	Reliability	Resolution	Small Market Demand	Speed	System-Level Problem	Workforce
Applied Research	4	3	10	11			6		6		6			1		
Production	2		1				1		3		1					
Market	3		1	2			1	1	4		1			1		
End-use			1						2	1	2					

Exhibit 11.13: MN Correlation Matrix for Stage of Technological Innovation and Measurement Solutions in Software for Information Technology

	Measurement Solutions																								
	Infrastructure								Products													Services			
Stage of Technological Innovation	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Applied Research	4	3	3	1	2	4	4	1		7		6	10		5	1		1		2	1				1
Production			1	1	2		2						1		2				1	1					
Market			1		1	1	2		1		1	1	1	1	2	2									
End-use												1	3										1		

Exhibit 11.14: MN Correlation Matrix for Solution Providers and Stage of Technological Innovation in Software for Information Technology

Measurement Solution Providers	Stage of Technological Innovation			
	Applied Research	Production	Market	End-Use
Calibration laboratories				
Commercial calibration service providers				
Component suppliers	1	1		
Contractor R&D labs-for-hire	2			
Engineering management/consulting firms/A&E firms	1			
Government laboratories and agencies	10	4	5	3
Independent testing/certification laboratories				1
Industrial R&D laboratories	8	3	1	1
Industry consortium/partnership	2		3	
Instrument suppliers	2			
Material suppliers				
National Measurement Institute	13	3	4	3
Small business/inventors				
Software developers	7	1		
Standards development organizations (SDOs)	1			
Testing laboratories				
Universities	12		2	

Exhibit 11.15: MN Correlation Matrix for Stage of Technological Innovation and TI as Measurement Technology in Software for Information Technology

Stage of Technological Innovation	TI as Measurement Technology
Applied Research	8
Production	1
Market	3
End-use	

Exhibit 11.16: MN Correlation Matrix for TI as Measurement Technology and Measurement Barriers in Software for Information Technology

Innovation Equivalency	Measurement Solution Barriers															
	Acceptability/Compatibility	Accessibility	Accuracy	Data, Data Collection and/or Retrieval	Destructive	Expense	Lack of fundamental knowledge	Multiple Solutions Exist	Not Standardized	Production Readiness	Reliability	Resolution	Small Market Demand	Speed	System-Level Problem	Workforce
Technology Innovation = Measurement Innovation	3	2	4	8			3	1	6		1			1		

Exhibit 11.17: MN Correlation Matrix for Solution Providers and TI as Measurement Technology in Software for Information Technology

Measurement Solution Providers	Technology Innovation = Measurement Innovation
Calibration laboratories	
Commercial calibration service providers	
Component suppliers	
Contractor R&D labs-for-hire	
Engineering management/consulting firms/A&E firms	1
Government laboratories and agencies	6
Independent testing/certification laboratories	
Industrial R&D laboratories	3
Industry consortium/partnership	3
Instrument suppliers	
Material suppliers	
National Measurement Institute	11
Small business/inventors	
Software developers	3
Standards development organizations (SDOs)	
Testing laboratories	
Universities	5

Exhibit 11.18: MN Correlation Matrix for TI as Measurement Technology and Measurement Solutions in Software for Information Technology

	Measurement Solutions																								
	Infrastructure								Products													Services			
Innovation Equivalency	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Technology Innovation = Measurement Innovation	1	3	2		2		3	1	1	3	1	4	3	1	5	3					1				

Exhibit 11.19: MN Correlation Matrix for Regulation as Driver/Barrier and Measurement Solutions in Software for Information Technology

	Measurement Solutions																								
	Infrastructure								Products													Services			
Regulatory Issues	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Regulation is a Driver	1				2		3		1			1			1	2									
Regulation is a Barrier																									

Exhibit 11.20: MN Correlation Matrix for Solution Providers and Regulation as Driver/Barrier in Software for Information Technology

Measurement Solution Providers	Regulation is a Driver	Regulation is a Barrier
Calibration laboratories		
Commercial calibration service providers		
Component suppliers		
Contractor R&D labs-for-hire	1	
Engineering management/consulting firms/A&E firms		
Government laboratories and agencies	2	
Independent testing/certification laboratories		
Industrial R&D laboratories		
Industry consortium/partnership	3	
Instrument suppliers	1	
Material suppliers		
National Measurement Institute	4	
Small business/inventors		
Software developers		
Standards development organizations (SDOs)		
Testing laboratories		
Universities	1	

U.S. Measurement System

Measurement Need (MN) Data Book

Chapter 12. Entire Economy

Prepared by
Energetics Incorporated
for the
National Institute of Standards and Technology

April 2006

Reference List of MN Distribution Charts and MN Correlation Matrices

Exhibit 12.1: MN Distribution of Measurement Barriers in Entire Economy

Acceptibility	Accessibility	Accuracy	Data, Data Collection & Retrieval	Destructive	Expense	Lack of Fundamental Knowledge	Multiple Solutions	Not Standardized	Production Readiness	Reliability	Resolution	Small market demand	Speed	Systems-level	Workforce	Total
27	9	188	94	8	17	75	12	84	13	80	58	1	31	8	1	706

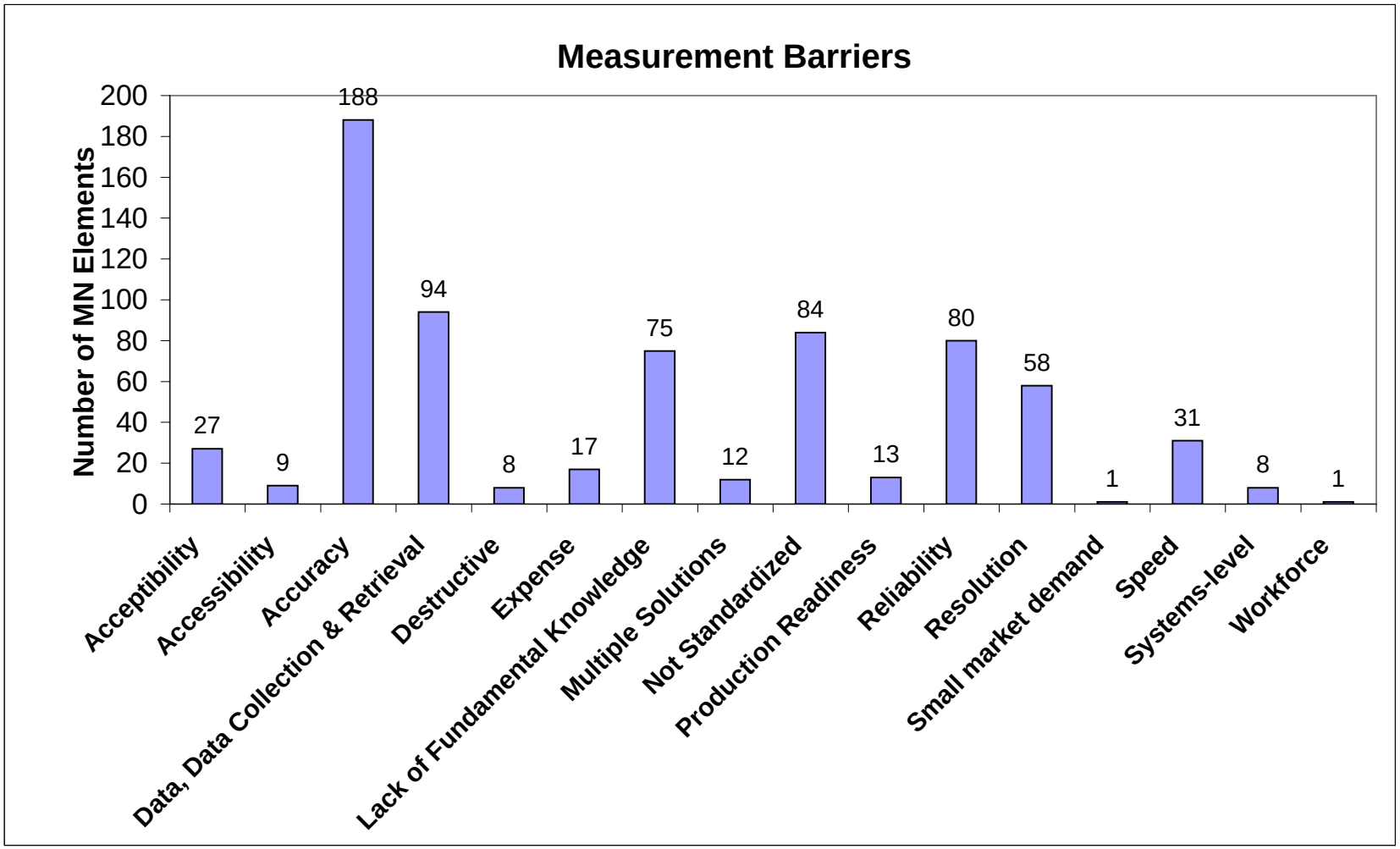

Exhibit 12.2: MN Distribution of Measurement Solution Providers in Entire Economy

Calibration Laboratories	Commercial Calibration Service Providers	Component Suppliers	Contractor R&D Labs-for-Hire	Engineering Management/Consulting Firms/A&E Firms	Government Laboratories and Agencies	Independent Testing/Certification Laboratories	Industrial R&D Laboratories	Industry Consortium/ Partnership	Instrument Suppliers	Material Suppliers	National Measurement Institute	Small Business/Inventors	Software Developers	Standards Development Organizations (SDO)	Testing Laboratories	Universities	Total
5	1	18	4	3	221	11	98	66	76	15	221	0	15	39	2	109	904

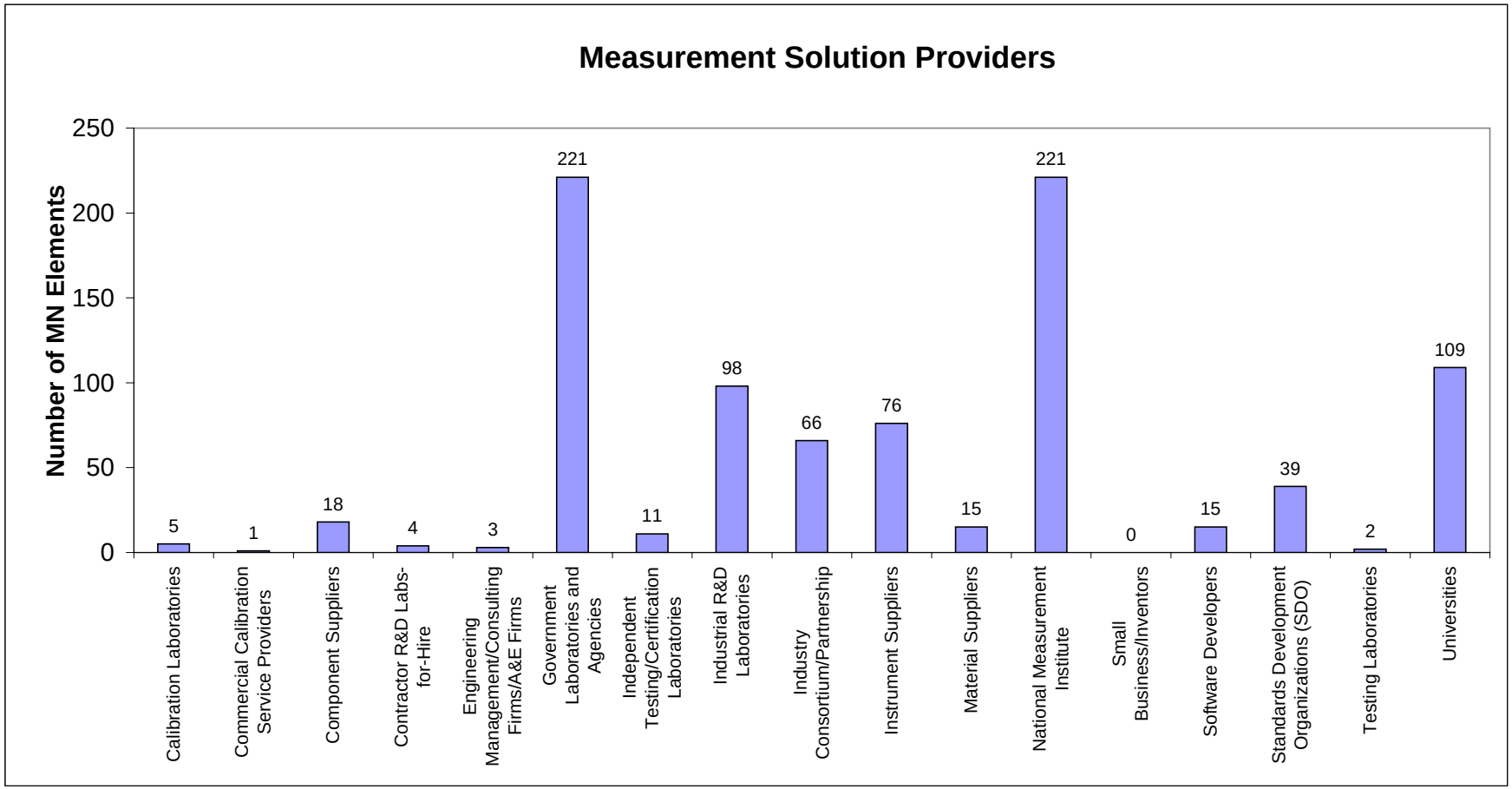

Exhibit 12.3: MN Distribution of Measurement Solutions in Entire Economy

Infrastructure								Products												Services				
Coordination/Facilitation	Data Collection/Retrieval	Development - Measurement Technology	Fund-amental Knowledge	Protocols	Research - Measure-ment Science	Standards	User Facility	Calibration	Computational Methods	Measure-ment Instrument	Measure-ment Method	Metrics/Benchmarks	Raw Data	Reference Data	Software	Stability Tests	Standard/certified reference material	Test methods for production-scale measurements	Test methods or test data for consumer products	Validated (hardened) properties data	Calibration	Expert consultation	Intl Recognition	Third Party Verification	Total
11	16	120	23	36	52	102	14	30	48	46	82	39	18	32	8	1	35	29	16	9	2	2	3	9	783

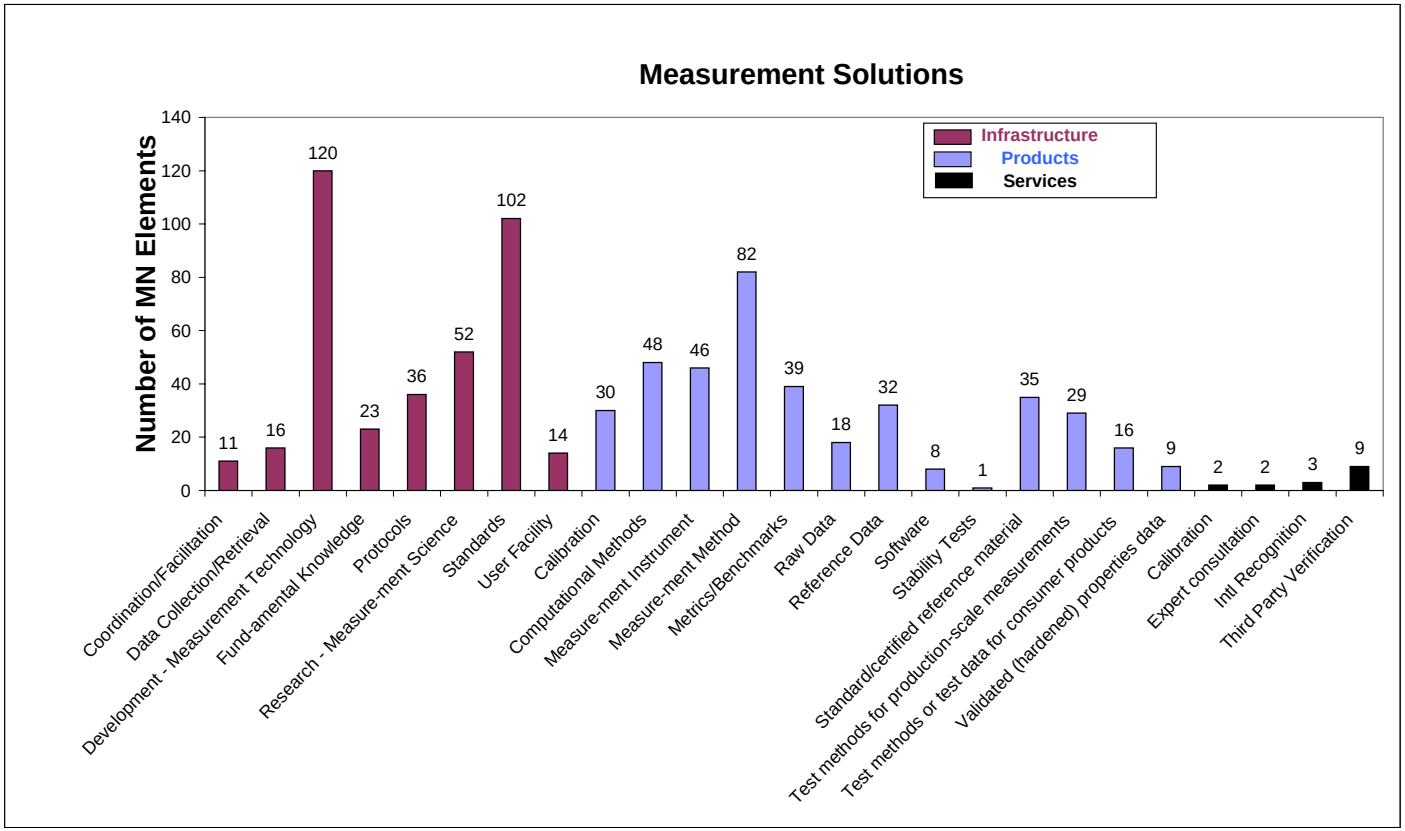

Exhibit 12.4: MN Distribution of Measurands in Entire Economy

Classical				Functional									Performance			Structural				
Biological	Chemical	Physical	Physiological	Acoustical	Electronic/ Electrical	Magnetic	Optical	Photonic	Radio frequency	Thermal- Thermochemical	Thermal- Thermodynamic	Thermal- Thermophysical	Computational Performance	Software Performance	System Performance	Kinetic	Mechanical	Molecular	Spatial	Total
24	26	73	8	3	37	15	22	13	6	2	9	14	7	12	23	1	15	7	5	322

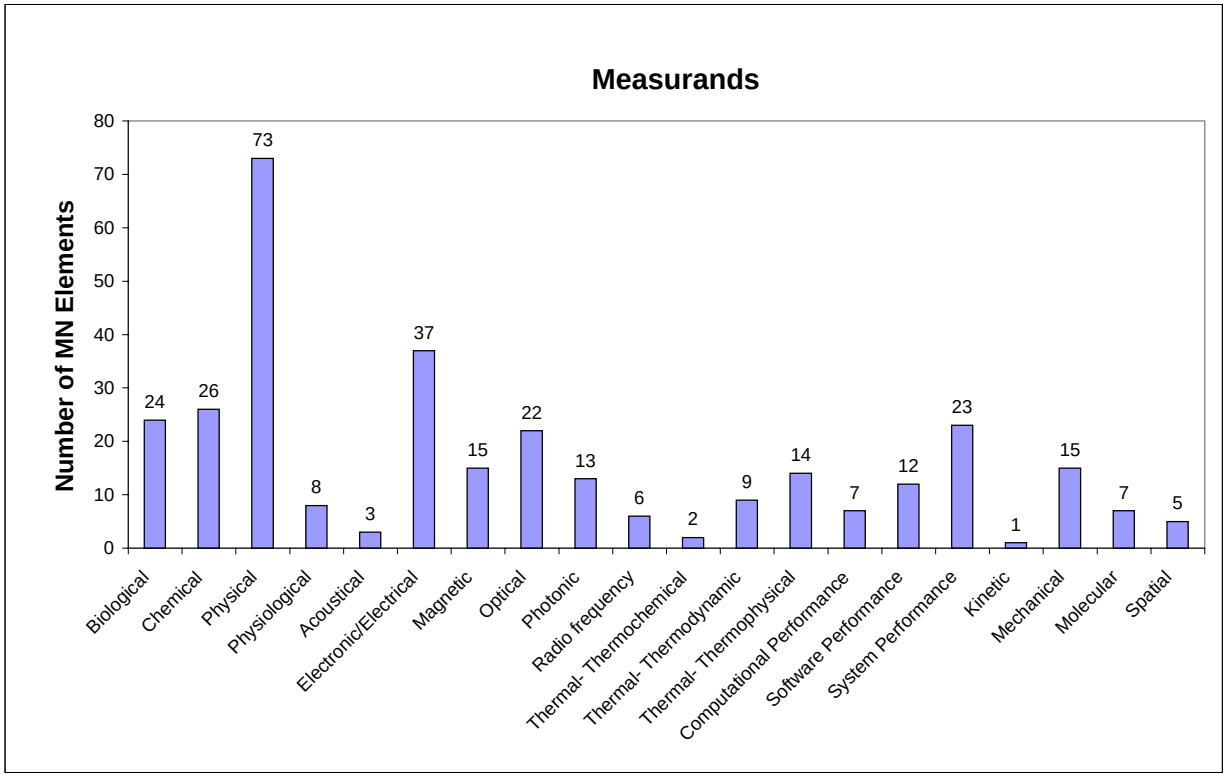

Exhibit 12.5: MN Distribution of Current Public/Private R&D Efforts in Entire Economy

Only Private Efforts Exist	Only Public Efforts Exist	Both Public and Private Efforts Exist	No Efforts Exist
37	41	93	151

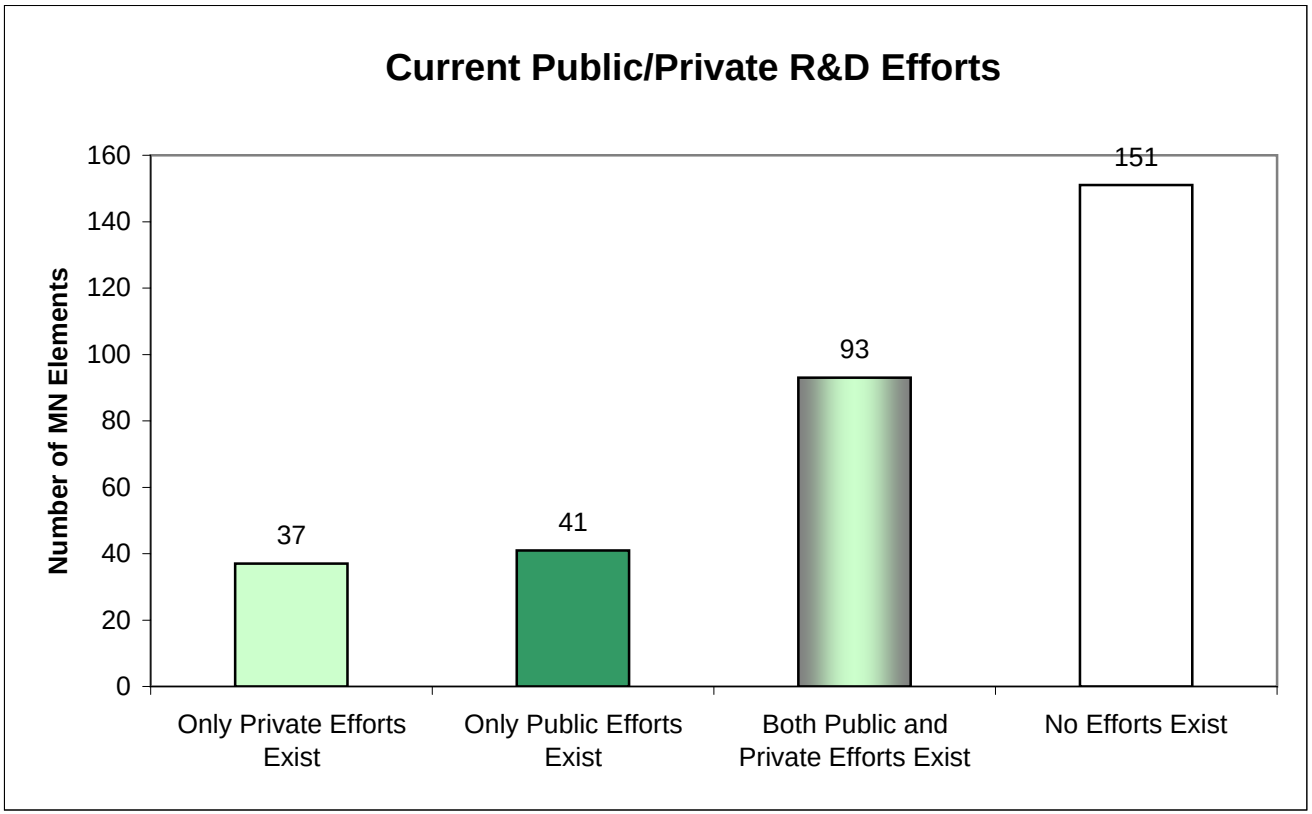

Exhibit 12.6: MN Distribution of TI as Measurement Technology in Entire Economy

Technology Innovation is a Measurement Innovation	Technology Innovation is not a Measurement Innovation
136	186

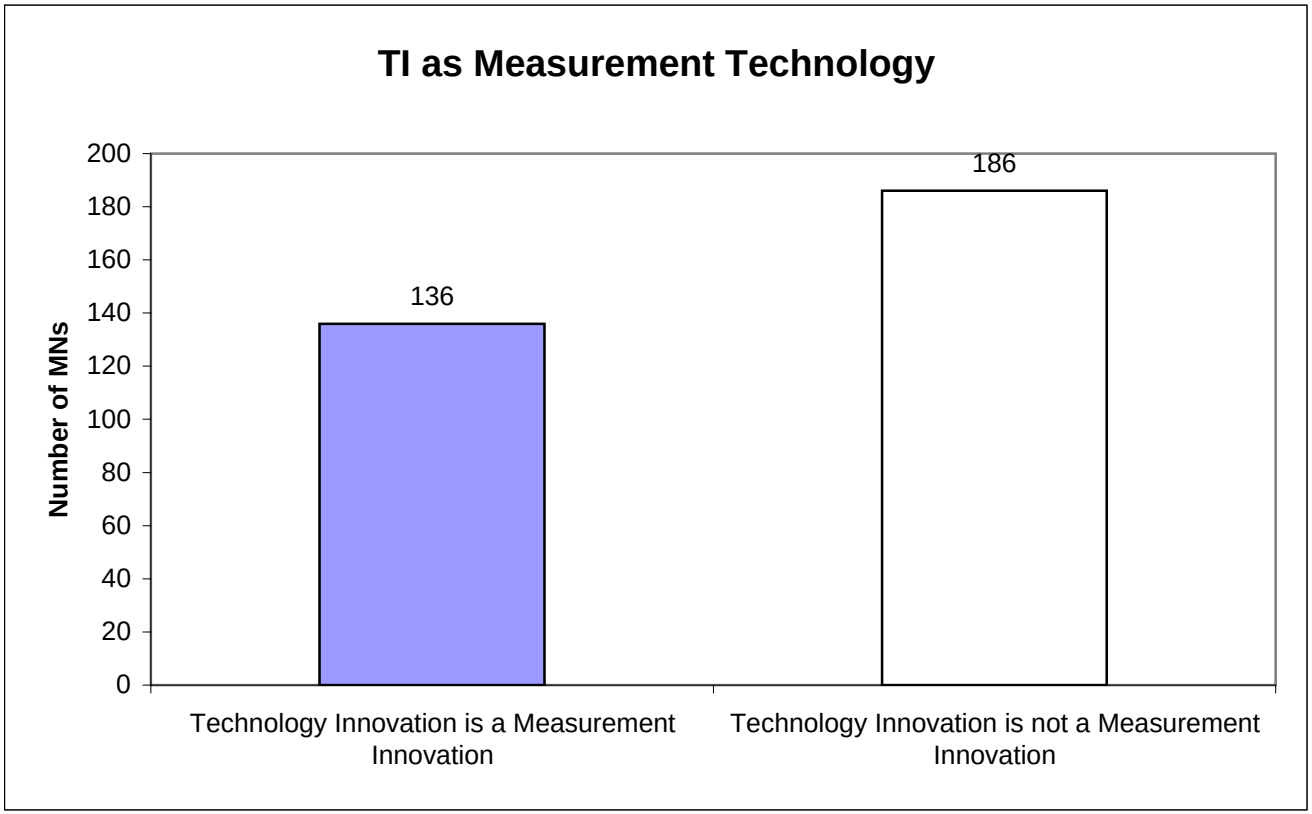

Exhibit 12.7: MN Distribution by Stage of Technological Innovation in Entire Economy

Applied Research	Production	Market	End-use	Total
227	42	41	12	322

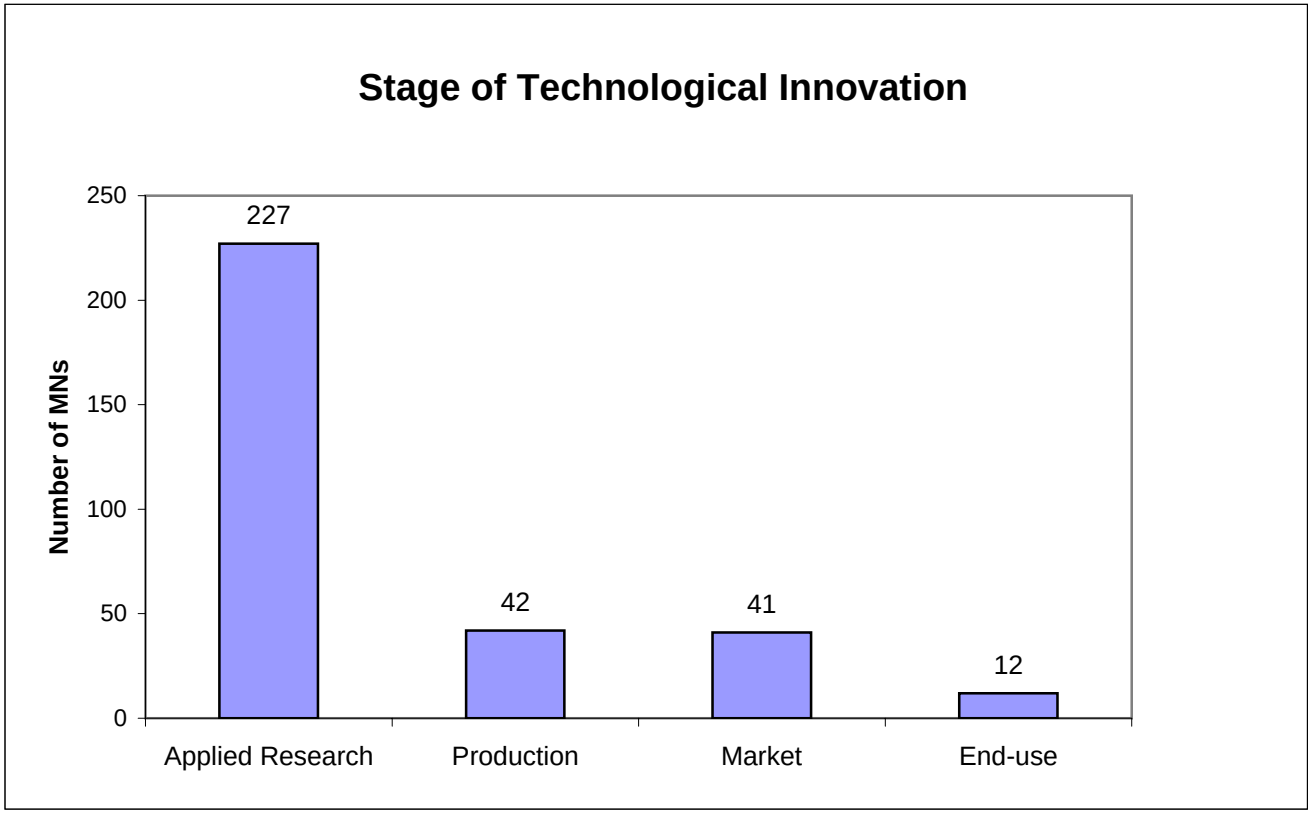

Exhibit 12.8: MN Distribution of Regulation as Driver/Barrier in Entire Economy

MN Driver	MN Barrier	No Impact
30	12	280

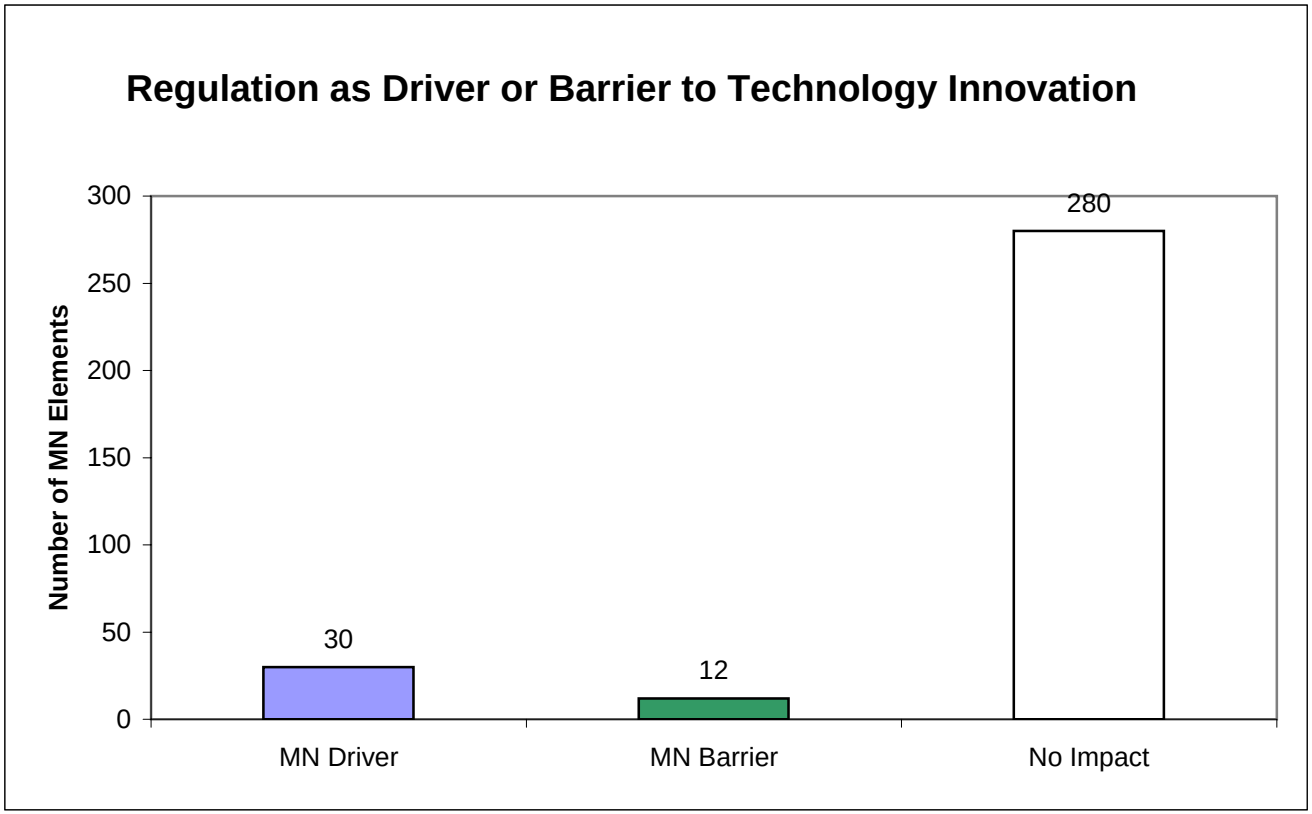

Exhibit 12.9: MN Correlation Matrix for Solution Providers and Measurement Barriers in Entire Economy

Solution Providers	Measurement Solution Barriers															
	Acceptability/Compatibility	Accessibility	Accuracy	Data, Data Collection and/or Retrieval	Destructive	Expense	Lack of fundamental knowledge	Multiple Solutions Exist	Not Standardized	Production Readiness	Reliability	Resolution	Small Market Demand	Speed	System-Level Problem	Workforce
Calibration laboratories	1		5	1		1			1		1					
Commercial calibration service providers				1					1							
Component suppliers	2		10	3		2	1	2	8		5	3				
Contractor R&D labs-for-hire	1		4	2			1		1		2					
Engineering management/consulting firms/A&E firms		1		1					1		1				1	
Government laboratories and agencies	13	4	128	51	4	11	58	6	51	10	48	44		22	5	1
Independent testing/certification laboratories	3		5	5			1		5		4			1		
Industrial R&D laboratories	7		51	17	3	1	31	4	27	4	19	20		7	2	
Industry consortium/partnership	7	4	40	22	3	8	15	2	17	2	18	14	1	13	2	
Instrument suppliers	9	3	49	21	2	5	14	1	22	6	19	16	1	4	2	
Material suppliers	2	1	7	9			5	2	7	1	2	2		2		
National Measurement Institute	17	8	130	64	6	10	50	7	61	10	58	39	1	22	8	1
Small business/inventors																
Software developers	4	2	9	7	1		1		3		5	2		1		
Standards development organizations (SDOs)	6	1	16	16	1	2	4	4	17	1	9	6		2	1	
Testing laboratories			1	1				1	2		1					
Universities	5	3	66	42	2	7	33	7	13	4	28	21		14		1

Exhibit 12.10: MN Correlation Matrix for Measurement Barriers and Measurement Solutions in Entire Economy

	Measurement Solutions																								
	Infrastructure								Products													Services			
Measurement Solution Barriers	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Acceptability/Compatibility	2	2	6	1	4	3	15	1	3	2	2	5	5	1	3	2		3	5	3				3	1
Accessibility	2	1	1		1		3	1	3	1	1	5			1	1		1	1						1
Accuracy	4	8	86	7	18	35	59	12	26	23	32	47	20	13	12	3	1	25	14	6	3	2	2	1	4
Data, Data Collection/and or Retrieval	6	15	20	6	12	11	31	8	10	29	17	23	11	11	12	2		12	10	11	7			1	6
Destructive	1		2	1	1	2	1		1	3	3	6						2			1				
Expense		3	7			6	6	1	3	2	6	3	1		1	1		4	3		1				1
Lack of Fundamental Knowledge	2	3	31	20	6	25	15	2	4	14	15	16	8	4	9	2	1	8	5	2	1				
Multiple Solutions Exist		1	6	1		2	4	2	3		3	5	2	2	1									1	1
Not Standardized	4	1	15	3	17	6	47	2	9	7	8	20	15	5	10	5		13	9	12	5		1	1	5
Production Readiness			9	1	1	1					1	2	1	1	2				3						
Reliability	3	5	24	5	9	11	28	2	11	16	9	23	17	7	9	2	1	12	9	5	4	1	1		6
Resolution	1	2	40	4	3	12	12	7	5	10	14	16	4	4	2			4	4	1			1		
Small Market Demand							1						1					1							
Speed	1	2	18	1	4	6	8	1	1	6	13	11	1		3			4	1						
System-Level Problem	2	1	3		3	2	2		1			1	2			1			1	1					
Workforce			1	1								1													

Exhibit 12.11: MN Correlation Matrix for Measurement Providers and Measurement Solutions in Entire Economy

	Measurement Solutions																									
	Infrastructure								Products														Services			
Measurement Solution Providers	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Calibration laboratories			1			1	3		2			1		1				1	1			1		1	
Commercial calibration service providers									1		1				1										
Component suppliers			6		2	2	9	1	1	1	3	4	2		1	1		1	2						2
Contractor R&D labs-for-hire	1						1		1	1	2	1	1					1		1	1				
Engineering management/consulting firms/A&E firms	1	1			1							1				2		1		1					
Government laboratories and agencies	7	8	87	19	27	38	63	8	13	28	29	52	28	14	24	6	1	21	16	12	5	1	1		3
Independent testing/certification laboratories		1			1	2	6		1	2	1	4	2	1	1			2	2	1				2	1
Industrial R&D laboratories	2	4	40	7	10	19	24	3	5	10	12	27	17	7	11	1		3	10	5	2		1		2
Industry consortium/partnership	1	3	26	4	9	13	23	2	6	12	18	16	6		4	4		8	8	3	6				2
Instrument suppliers	2	2	37	8	10	13	28	3	11	11	11	12	4	4	3		1	8	10	3	1				2
Material suppliers	1	1	5	1	2	5	8	2	1	3	1	3	1	2				4	1		1			1	
National Measurement Institute	7	9	79	13	25	31	69	11	27	32	34	59	27	9	24	7	1	29	17	13	5	2	2	2	7
Small business/inventors																									
Software developers	2	3	1	2	1	1	3		1	7		4	5		3	1		2	1	1					1
Standards development organizations (SDOs)	2	4	8		8	1	22	1		2	1	12	6	1	2			9	7	4				2	4
Testing laboratories			1				2					1						1							1
Universities	3	7	45	11	3	24	25	4	10	25	17	35	14	11	14	1		7	8	3	4			1	2

Exhibit 12.12: MN Correlation Matrix for Stage of Technological Innovation and Measurement Barriers in Entire Economy

Stage of Technological Innovation	Measurement Solution Barriers															
	Acceptability/Compatibility	Accessibility	Accuracy	Data, Data Collection and/or Retrieval	Destructive	Expense	Lack of fundamental knowledge	Multiple Solutions Exist	Not Standardized	Production Readiness	Reliability	Resolution	Small Market Demand	Speed	System-Level Problem	Workforce
Applied Research	12	7	142	66	7	11	65	9	43	8	50	50		25	4	1
Production	5	2	20	13	1	2	5	1	16	4	11	5		3	2	
Market	9		21	13		2	3	2	18		15	3	1	2	2	
End-use	1		5	2		2	2		7	1	4			1		

Exhibit 12.13: MN Correlation Matrix for Stage of Technological Innovation and Measurement Solutions in Entire Economy

	Measurement Solutions																								
	Infrastructure								Products													Services			
Stage of Technological Innovation	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Applied Research	6	10	97	19	16	46	60	13	24	37	41	63	22	15	21	2	1	18	17	8	7	1	1	1	5
Production	3	3	14	3	5	1	17	1	3	5	2	6	2		5	1		7	5	4	1	1			2
Market	1	2	6	1	11	3	21		2	5	2	11	11	3	4	3		9	7	4	1			2	2
End-use	1	1	3		4	2	4		1	1	1	2	4		2	2		1					1		

Exhibit 12.14: MN Correlation Matrix for Solution Providers and Stage of Technological Innovation in Entire Economy

Measurement Solution Providers	Stage of Technological Innovation			
	Applied Research	Production	Market	End-use
Calibration laboratories	2	1	1	1
Commercial calibration service providers	1			
Component suppliers	8	6	2	2
Contractor R&D labs-for-hire	4			
Engineering management/consulting firms/A&E firms	1	2		
Government laboratories and agencies	157	29	26	9
Independent testing/certification laboratories	4	3	3	1
Industrial R&D laboratories	76	12	7	3
Industry consortium/partnership	40	9	16	1
Instrument suppliers	55	13	7	1
Material suppliers	9	4	2	
National Measurement Institute	156	25	29	11
Small business/inventors				
Software developers	12	1	1	1
Standards development organizations (SDOs)	18	7	13	1
Testing laboratories	1		1	
Universities	93	8	8	

Exhibit 12.15: MN Correlation Matrix for Stage of Technological Innovation and TI as Measurement Technology in Entire Economy

Stage of Technological Innovation	TI as Measurement Technology
Applied Research	107
Production	11
Market	12
End-use	6

Exhibit 12.16: MN Correlation Matrix for TI as Measurement Technology and Measurement Barriers in Entire Economy

Innovation Equivalency	Measurement Solution Barriers															
	Acceptability/Compatibility	Accessibility	Accuracy	Data, Data Collection and/or Retrieval	Destructive	Expense	Lack of fundamental knowledge	Multiple Solutions Exist	Not Standardized	Production Readiness	Reliability	Resolution	Small Market Demand	Speed	System-Level Problem	Workforce
Technology Innovation = Measurement Innovation	9	4	90	48	2	8	36	5	38	4	33	29		9	3	

Exhibit 12.17: MN Correlation Matrix for Solution Providers and TI as Measurement Technology in Entire Economy

Measurement Solution Providers	Technology Innovation = Measurement Innovation
Calibration laboratories	5
Commercial calibration service providers	1
Component suppliers	4
Contractor R&D labs-for-hire	2
Engineering management/consulting firms/A&E firms	2
Government laboratories and agencies	89
Independent testing/certification laboratories	4
Industrial R&D laboratories	35
Industry consortium/partnership	20
Instrument suppliers	38
Material suppliers	8
National Measurement Institute	103
Small business/inventors	
Software developers	8
Standards development organizations (SDOs)	12
Testing laboratories	1
Universities	42

Exhibit 12.18: MN Correlation Matrix for TI as Measurement Technology and Measurement Solutions in Entire Economy

	Measurement Solutions																								
	Infrastructure								Products														Services			
Innovation Equivalency	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Technology Innovation = Measurement Innovation	4	11	46	7	15	24	48	7	20	19	23	34	11	10	16	8	1	16	13	6	5	2	1	1	3

Exhibit 12.19: MN Correlation Matrix for Regulation as Driver/Barrier and Measurement Solutions in Entire Economy

	Measurement Solutions																							
	Infrastructure								Products													Services			
Regulatory Issues	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Regulation is a Driver	2	2	5		6	5	14		2	4	3	8	3	2	2	5		6	7	1	2				2
Regulation is a Barrier		4					7		1	5	1	2	3	1	2			3	2	1				2	2

Exhibit 12.20: MN Correlation Matrix for Solution Providers and Regulation as Driver/Barrier in Entire Economy

Measurement Solution Providers	Regulation is a Driver	Regulation is a Barrier
Calibration laboratories	1	2
Commercial calibration service providers		
Component suppliers		
Contractor R&D labs-for-hire	1	
Engineering management/consulting firms/A&E firms	1	
Government laboratories and agencies	20	6
Independent testing/certification laboratories	3	3
Industrial R&D laboratories	8	2
Industry consortium/partnership	10	2
Instrument suppliers	3	2
Material suppliers		2
National Measurement Institute	25	10
Small business/inventors		
Software developers		
Standards development organizations (SDOs)	5	2
Testing laboratories		1
Universities	8	3

Exhibit 12.21: MN Correlation Matrix for Economic Sector/Technology Areas and Measurement Barriers in Entire Economy

	Measurement Solution Barriers															
Economic Sector/Technology Areas	**Acceptability/Compatibility**	**Accessibility**	**Accuracy**	**Data, Data Collection and/or Retrieval**	**Destructive**	**Expense**	**Lack of fundamental knowledge**	**Multiple Solutions Exist**	**Not Standardized**	**Production Readiness**	**Reliability**	**Resolution**	**Small Market Demand**	**Speed**	**System-Level Problem**	**Workforce**
Agriculture and Food Processing			5	2					1		3	1				
Building and Construction - Civil Infrastructure	2		3	6			3	1	3		2				1	
Building and Construction - Residential / Commercial Building	3		7	13		1	4	3	9	1	5	1		1	1	
Chemical			3	3			1				1	1				
Defense	1	1	10	4	1	2	6		4		5	1		1		
Electronics - Non-semiconductor	4	4	40	13		4	12	3	19	8	13	10		4		
Electronics - Semiconductor	2	1	38	8	1	6	13		3	2	12	22		13		
Energy and Power - Fossil fuel	1		2				1							1		
Energy and Power - Hydrogen			2	5	1		3		4	1	1	1				
Energy and Power - Nuclear			1								1					
Energy and Power - Power Generation and Distribution	1	1	8	7			2	1	4		3	1		1		
Energy and Power - Renewable			2	1			1									
Environment			2	6			1		3		2	1				
Healthcare - Bioimaging and Informatics	4		23	10	1	4	14	2	8	1	8	7		2	2	
Healthcare - Clinical Diagnostics	3	1	26	10		4	13	2	12		12	5		2	1	
Healthcare - Health and Safety	1		13	6			8	1	6		5	3		1	2	
Healthcare - Pharmaceuticals	2		16	8	1	2	8	2	5		10	5		3		1
Homeland Security - First Responders	4		12	10		1	5		16	1	8	3	1	3		
Industrial Biotechnology	2	1	3	4	1	3	3	1	2		1	1		3		
Information Technology - Software	9	3	13	13			8	1	15	1	10			2		
Information Technology - Hardware	2		16	3	1	3	7		8	1	4	4		5	1	
Manufacturing - Continuous	1	1	5	7			3	1	2	1	5	2			1	
Manufacturing - Discrete	2	2	11	7	2	2	2		3		5	8		3	1	
Materials - Ceramics	1		5	2		1	4	1		2	1	3				
Materials - Metals	2	2	8	8	1		1	2	2		2	5		1		
Materials - Polymers	2	1	10	9	1	1	9	2	4	2	2	5		1		1
Measurement Technology - Instrumentation	3	1	44	16	2	6	14	1	20	1	17	19		10	2	
Measurement Technology - Process Control	5		6	9			3		5	1	5	3		4	1	
Measurement Technology - SI Units		1	11	4	1	1	2		4		7	4				
Nanotechnology	1		29	12	2	3	7	2	5		6	22		9		1
Other	1	1	1				1		1			1				
Other - Law Enforcement	1						1					1				
Telecommunications	3	1	13	7	1		3		8	1	10	3		2	4	
Transportation - Aerospace	1	1	9	4		2		2	3		6					
Transportation - Automotive	3	2	11	15	2	2	5	2	7	1	9	3		2		

Exhibit 12.22: MN Correlation Matrix for Economic Sector/Technology Areas and Measurands in Entire Economy

	Classical				Functional									Performance			Structural			
Economic Sector/Technology Areas	**Biological**	**Chemical**	**Physical**	**Physiological**	**Acoustical**	**Electronic/Electrical**	**Magnetic**	**Optical**	**Photonic**	**Radio frequency**	**Thermal- Thermochemical**	**Thermal- Thermodynamic**	**Thermal- Thermophysical**	**Computational Performance**	**Software Performance**	**System Performance**	**Kinetic**	**Mechanical**	**Molecular**	**Spatial**
Agriculture and Food Processing	2	1	1			1														
Building and Construction - Civil Infrastructure			1						1			1	2	1				2		1
Building and Construction - Residential / Commercial Building		1	3	2		3			1			1	4	1		3		2		2
Chemical		2										1	1							
Defense	1	2	4			1		2	1							2	1			
Electronics - Non-semiconductor		4	22	1		17	9	5	4	2		2	2	1		1		3	2	1
Electronics - Semiconductor		3	19			13	3	6	1	1			2					2	2	
Energy and Power - Fossil fuel		1	2																	
Energy and Power - Hydrogen		2	1			1					2							1		
Energy and Power - Nuclear			1																	
Energy and Power - Power Generation and Distribution		1	3			4	2					1	1							
Energy and Power - Renewable						1		1												
Environment			1	1	1	2		1	1											
Healthcare - Bioimaging and Informatics	8	1	1	3			6	4	1						4	4		1	1	
Healthcare - Clinical Diagnostics	19	1	1	2			2	2	2					1	1	3		1	1	
Healthcare - Health and Safety	4	4	3			2		2	1	1		1	1			1		1		
Healthcare - Pharmaceuticals	10	4	5			1			1			2							1	
Homeland Security - First Responders	1	1	3		2		3	2	1	2			1			7		1		1
Industrial Biotechnology	4	3	2																	
Information Technology - Software			4		2	1		1		1			1	5	10	7				1
Information Technology - Hardware		1	10			3	1	1		2				2		6		1		
Manufacturing - Continuous						1	1	2					2	1	1			2		
Manufacturing - Discrete			8					1					2	1	1	1	1	2		1
Materials - Ceramics		1	1						1			1	2			1			3	
Materials - Metals		3	2				3		1							1		3		
Materials - Polymers		5	6	1		4				1		1				1		2	2	
Measurement Technology - Instrumentation	6	2	17	2	1	5	2	5	3			3	3		1	5		1	1	3
Measurement Technology - Process Control		2	5							1			1			4		2		1
Measurement Technology - SI Units			4	1	1	1		2	1	1		1	1					2		
Nanotechnology		5	19	1		3	1	3	1				1					1	1	
Other		1			1			1				1								
Other - Law Enforcement		1						1												
Telecommunications		1	1		1	4		1	3	3						7		1		
Transportation - Aerospace		1	1					2				1		1		1	1	3		
Transportation - Automotive		2	8	2		1				1	1	1		1		1		3		3

Exhibit 12.23: MN Correlation Matrix for Economic Sector/Technology Areas and Stage of Technological Innovation in Entire Economy

	Stage of Technological Innovation			
Economic Sector/Technology Areas	Applied Research	Production	Market	End-use
Agriculture and Food Processing	2		2	1
Building and Construction - Civil Infrastructure	6	1	2	
Building and Construction - Residential / Commercial Building	13	1	8	1
Chemical	4			
Defense	13	1		
Electronics - Non-semiconductor	49	14	11	2
Electronics - Semiconductor	44	6	1	1
Energy and Power - Fossil fuel	2		1	
Energy and Power - Hydrogen	5	1	1	
Energy and Power - Nuclear	1			
Energy and Power - Power Generation and Distribution	7	2	2	1
Energy and Power - Renewable	1		1	
Environment	5		2	
Healthcare - Bioimaging and Informatics	21	2	9	2
Healthcare - Clinical Diagnostics	22		12	2
Healthcare - Health and Safety	16	2	3	
Healthcare - Pharmaceuticals	19	3	2	
Homeland Security - First Responders	19	1	3	2
Industrial Biotechnology	6	2	1	
Information Technology - Software	21	4	5	3
Information Technology - Hardware	24		1	2
Manufacturing - Continuous	6	3	1	
Manufacturing - Discrete	14	3		1
Materials - Ceramics	8	2		
Materials - Metals	6	6	1	
Materials - Polymers	19	2	2	
Measurement Technology - Instrumentation	48	4	6	2
Measurement Technology - Process Control	10	5		1
Measurement Technology - SI Units	11	2	2	
Nanotechnology	31	4		1
Other	3		1	
Other - Law Enforcement	2			
Telecommunications	15	1	4	2
Transportation - Aerospace	7	2	1	1
Transportation - Automotive	15	6	2	1

Exhibit 12.24: MN Correlation Matrix for Economic Sector/Technology Areas and TI as Measurement Technology in Entire Economy

Economic Sector/Technology Areas	Technology Innovation = Measurement Innovation
Agriculture and Food Processing	2
Building and Construction - Civil Infrastructure	3
Building and Construction - Residential / Commercial Building	7
Chemical	2
Defense	8
Electronics - Non-semiconductor	17
Electronics - Semiconductor	18
Energy and Power - Fossil fuel	3
Energy and Power - Hydrogen	2
Energy and Power - Nuclear	1
Energy and Power - Power Generation and Distribution	4
Energy and Power - Renewable	
Environment	3
Healthcare - Bioimaging and Informatics	22
Healthcare - Clinical Diagnostics	27
Healthcare - Health and Safety	8
Healthcare - Pharmaceuticals	15
Homeland Security - First Responders	14
Industrial Biotechnology	3
Information Technology - Software	12
Information Technology - Hardware	5
Manufacturing - Continuous	7
Manufacturing - Discrete	13
Materials - Ceramics	4
Materials - Metals	2
Materials - Polymers	6
Measurement Technology - Instrumentation	41
Measurement Technology - Process Control	11
Measurement Technology - SI Units	10
Nanotechnology	15
Other	2
Other - Law Enforcement	1
Telecommunications	9
Transportation - Aerospace	5
Transportation - Automotive	11

Exhibit 12.25: MN Correlation Matrix for Economic Sector/Technology Areas and TI as Measurement Technology in Entire Economy

	Measurement Solutions																										
	Infrastructure								Products														Services				
Economic Sector/Technology Areas	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Agriculture and Food Processing			1		4	2	1		1		1	1			1			1								
Building and Construction - Civil Infrastructure		1	3	1	1	3	4			3	1	2	2		1				1		1					
Building and Construction - Residential / Commercial Building		2	5	2	2	6	11			7	2	7	5	2	3			1	2	4	2					1
Chemical	1	1	1	1		1	1	1		2	1															
Defense		1	2	3		2	2	2	3		4	5	1	3	2		1	2	2		1					1
Electronics - Non-semiconductor	1		34	5	8	8	28	3	7	7	8	12	3	2	3	1		3	9	1	2			1		3
Electronics - Semiconductor			31	2	2	12	8	5	7	10	16	13	1	3	2	1		7	6		1	1	1			1
Energy and Power - Fossil fuel							1		1			1			1									1		
Energy and Power - Hydrogen	1		2	1		1	3	1			1	1	1	2					3	1	1					
Energy and Power - Nuclear			1			1			1																	
Energy and Power - Power Generation and Distribution	1	1	2		1	1	4	2	3	4		3		3	1			2	2	1	1	1		1		
Energy and Power - Renewable			1	1		2													1							
Environment		1	1	1		1	2		3	3	1	1	1	1	1				2							1
Healthcare - Bioimaging and Informatics	2	3	10		9	6	12	2	4	4	6	9	7	2	3	4		7	5	1	2					
Healthcare - Clinical Diagnostics		4	8	4	7	9	13	2	3	4	4	11	4	3	7	5		10	3		1					1
Healthcare - Health and Safety	1		7	1	4	1	7		5	3	3	7	2	1	4		1	2		5						
Healthcare - Pharmaceuticals		3	10	5	3	7	10	1	3	2	2	11	2		4			5	1	1						
Homeland Security - First Responders		1	6	1	4	1	8		3	4	6	9	6	2	3			3	1	6	1		1			2
Industrial Biotechnology			3	2	1	2	3	1	2		2	6			1			2	1	1						
Information Technology - Software	4	3	5	2	5	5	8	1	1	7	1	8	15	1	9	3		1	1	3	1		1			1
Information Technology - Hardware	2		13	1	2	7	9	1	1	3	2	8	5		2			3	2	2						
Manufacturing - Continuous	2	3	3	1		1	4	1	2	2	2	1			2	1				1						2
Manufacturing - Discrete	2	2	6	1			4	2	4	3	7	6	1		2	1		3	2	1			1			2
Materials - Ceramics		1	5	1		1	1	1		2		2	1		3									1		
Materials - Metals	2	1	4			2	4	1	1	5		6			1			3	2		1			2		1
Materials - Polymers		1	9	5	4	5	7	1		3	2	10	1	5	1			1							1	1
Measurement Technology - Instrumentation	2	3	27	3	10	12	24	2	9	8	15	11	5	4	5	3	1	6	3	8	1					2
Measurement Technology - Process Control	1	1	9	1	3		5	1	1	2	4	4	2	1	1			2	5	1			1			
Measurement Technology - SI Units		1	5	2		1	4		5	4	5	3	2			1		2				1				
Nanotechnology		1	23	1	4	13	9	2	4	6	12	8	2	4	1			7	2			1				
Other							1			1		2		1	1	1										
Other - Law Enforcement										1					1											
Telecommunications	1		11		6	4	8	1	3	1	2	11	5					1	3	2			1			
Transportation - Aerospace	2	2	3	1		1	2	1	3	2	3	2	2					3								1
Transportation - Automotive	3	4	6	3		5	9	2	3	7	3	4	1	4				1	7	1	2					3

Exhibit 12.26: MN Correlation Matrix for Economic Sector/Technology Areas and TI as Measurement Technology in Entire Economy

	Solution Providers																	
Economic Sector/Technology Areas	**Calibration laboratories**	**Commercial calibration service providers**	**Component suppliers**	**Contractor R&D labs-for-hire**	**Engineering management/consulting firms/A&E firms**	**Government laboratories and agencies**	**Independent testing/certification laboratories**	**Industrial R&D laboratories**	**Industry consortium/partnership**	**Instrument suppliers**	**Material suppliers**	**National Measurement Institute**	**Small business/inventors**	**Software developers**	**Standards development organizations (SDOs)**	**Testing laboratories**	**Universities**
Agriculture and Food Processing						4		1	1	2		4			1		
Building and Construction - Civil Infrastructure			1			3	2		5	2	1	4		1	2	1	3
Building and Construction - Residential / Commercial Building			2			11	3	5	7	3	1	15		1	8	1	8
Chemical						4		1	1	1		3		1			1
Defense			1	1		9		3		4	1	12		1			6
Electronics - Non-semiconductor			12	1		53	2	19	14	29	2	41		2	7		33
Electronics - Semiconductor	1			1		34		16	22	10	2	38		2	1		19
Energy and Power - Fossil fuel	1					2	1	1				3					
Energy and Power - Hydrogen	1					6		5		1		6			1		
Energy and Power - Nuclear										1		1					
Energy and Power - Power Generation and Distribution	3					6	1	3		1	2	10			1		5
Energy and Power - Renewable						2		2							1		1
Environment		1	1			5	1	2	2	1		3		1	1		3
Healthcare - Bioimaging and Informatics			1		1	26		14	8	5	1	26		1	6		10
Healthcare - Clinical Diagnostics			1			26	1	12	10	6	2	24		2	4	1	14
Healthcare - Health and Safety	1					13	1	8	4	4		19			4		6
Healthcare - Pharmaceuticals	1					15	2	7	4	6		14		1	4		15
Homeland Security - First Responders		1		2	1	18		4	3	9		22		1	5		5
Industrial Biotechnology						6	1		5	2		6			2		4
Information Technology - Software			2	2	1	22	1	13	5	2		23		8	1		14
Information Technology - Hardware	1		2	1		21		13	6	4	1	14		1	2		13
Manufacturing - Continuous			1		1	3		1		4	1	7		3	1		4
Manufacturing - Discrete					1	6		5	2	5		14		2	3		7
Materials - Ceramics						8		3	2		1	7			2		4
Materials - Metals						5	1	3	6	1	4	8			4		5
Materials - Polymers			1			18	1	4	3	8	3	13			6		10
Measurement Technology - Instrumentation	1	1	1		1	42	1	8	19	20	1	49		2	4		15
Measurement Technology - Process Control			1			8	1	6	2	7	2	10			2		4
Measurement Technology - SI Units			1		1	7		1	3	7	2	11		2			2
Nanotechnology	1					25	1	6	11	11	6	24		1	1		15
Other					1	2	1	2		1		3		1	1		
Other - Law Enforcement						2		1		1		2					
Telecommunications			2			14		6	2	8	2	15			4		6
Transportation - Aerospace			1			6		1	2	2	1	9		2	3		4
Transportation - Automotive	1		3			11	1	7	7	5	2	19		1	2		6

Exhibit 12.27: Total MN Distribution (All Groups)

Agriculture & Food Processing	Building and Con-struction	Chemicals, Industrial Biotech, Continuous Mfg	Defense & Homeland Security	Electronics (Non-semiconductor) and IT Hardware	Electronics (semiconductor)	Energy, Power & Environment	Healthcare	Manufacturing (Discrete)	Materials	Measurement Technology	Nano-technology	Other	Other - Law Enforcement	Software for IT	Telecommunications	Transportation - Aerospace	Total
5	23	22	35	52	52	27	77	32	40	91	36	1	2	33	18	7	553